Movement Matters: Effects of Motion and Mimicry on Perception of Similarity and Closeness in Robot-Mediated Communication

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ABSTRACT
In face-to-face interaction, moving with and mimicking the body movements of communication partners has been widely demonstrated to affect interpersonal processes, including feelings of affiliation and closeness. In this paper, we examine effects of movement and mimicry in robot-mediated communication. Participants were instructed to get to know their partner, a confederate, who interacted with them via a telepresence robot. The robot either (a) mimicked the participant's body orientation (mimicry condition), (b) mimicked pre-recorded movements of another participant (random movement condition), or (c) did not move during the interaction (static condition). Results showed that mimicry and random movement had similar effects on participants' perceptions of similarity and closeness to their partners and that these effects depend on the participant's gender and level of self-monitoring. The findings suggest that the social movements of a telepresence robot affect interpersonal processes and that these effects are shaped by individual differences.

ACM Classification Keywords
H.4.3. Information Systems Applications: Communications Applications—*computer conferencing, teleconferencing, and videoconferencing*

Author Keywords
Robot-mediated communication; telepresence robots; nonverbal behavior; movement; mimicry; affiliation; similarity; closeness

INTRODUCTION
Communication technologies have radically transformed how people communicate at a distance. From written letters and phone-calls to e-mail, instant messaging, and videoconferencing, communication media have been developed to achieve more effective and efficient information exchange, especially among long distance communication partners. Recently, telepresence robots have been introduced as another option in distance communication. Telepresence robots, sometimes called mobile robotic presence (MRP) systems, are comprised by a video conferencing system mounted on a moving, physical robotic base [29]. By allowing operators to achieve a physical embodiment and freedom of motion in a remote location, these systems augment video conferencing or audio communication [29, 46] and provide long-distance communicators with a stronger sense of presence [43].

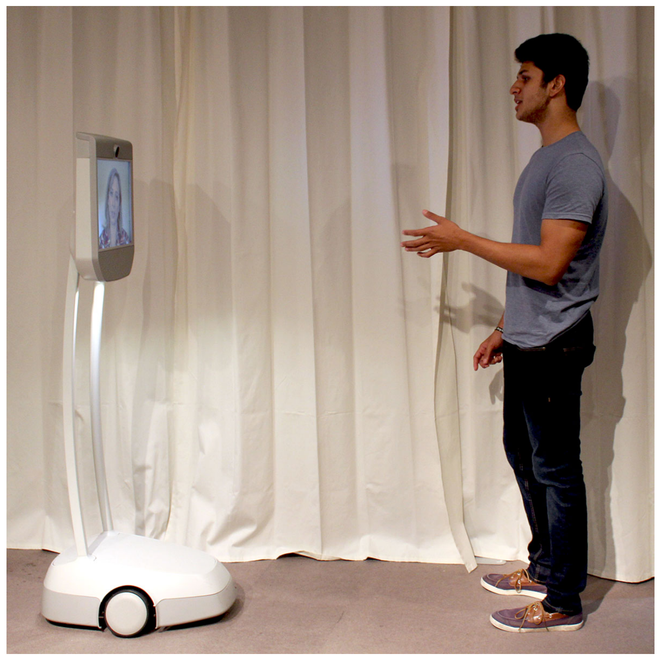

Figure 1. We explore how the bodily movements of a telepresence robot, including movements that mimic those of the local user, shape affiliation between local and remote users in robot-mediated communication.

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In organizations, telepresence robots provide a new platform for dynamic communication in various settings including business, education, and medicine [36, 58]. For example, corporations use telepresence robots for remote collaboration or to attend conferences at a lower cost compared to the expense of travel (e.g., flight, hotel, and rental car) [40]. In education, homebound or hospitalized students use telepresence robots to join the class in real time, interact with other students, and participate in group discussion [17]. Telepresence robots have been shown to be more efficient compared to communication channels that have become conventional (e.g., phone calls, videoconferencing) [26, 35, 40].

Along with its possibilities and potential for enriching remote communication, the emergence of robot-mediated communication also introduces many unknowns regarding how telepresence robots may support essential interpersonal processes that ensure the effectiveness of face-to-face communication. One component of effective communication is *rapport*, defined as relationships of affinity and trust within a group or between a dyad [6]. Building rapport is important in both our personal and professional lives. Personal relationships are easier to develop and maintain when there is greater rapport between the parties involved [57]. Workplace relationships involve rapport in the sense that frequent informal communication builds coordination and commitment between members of a team [63]. In healthcare contexts, rapport ensures that patients are willing to disclose relevant health information and are receptive to clinicians' care and guidance [7]. Rapport builds, in part, through nonverbal cues [11, 13], especially in informal interactions. For telepresence robots to contribute to effective communication across these contexts, users must be able to build rapport and a sense of affiliation.

In this paper, we study a specific nonverbal process that affects rapport between communication partners, *movement*. We present the design of and findings from a laboratory experiment that examined whether telepresence robots' movements affect how local users affiliate themselves with and perceive remote users in conversational interactions (Figure 1). As telepresence robots replicate many aspects of face-to-face communication, remote users may experience mediated interactions using telepresence robots as though they were "really there" with their communication partners and vice versa [55, 58]. We expect that the nonverbal cues underlying rapport and affiliation in a face-to-face context will also contribute to rapport between interactants in a robot-mediated context.

Background

This section reviews related work addressing the importance of nonverbal communication processes and provides a rationale for examining movement in robot-mediated communication.

Nonverbal Cues in Robot-Mediated Communication

Literature suggests several nonverbal factors that facilitate higher quality interpersonal communication using telepresence robots. Research shows that both physical embodiment and locus of system control–local vs. remote user– have an impact on interpersonal trust in mediated communication [45]. Specifically, granting the local user more control over the configuration of the telepresence unit led to greater trust between the communication partners. Height of the telepresence robot also affected the local user's perception of the remote partner [46]. When the telepresence system was shorter than the local partner, partners behaved in ways that showed more dominance, and they perceived the remote users to be less persuasive than when the telepresence system was taller than them [46]. This finding is consistent with interpersonal communication literature showing that taller people are viewed as more competent and are more likely to emerge as leaders [54, 65, 66]. In addition, spatial configuration, including body orientation of a telepresence robot toward the partner, can enhance interaction quality [30, 31, 33]. The researchers found that the robot's body rotation affects how people arrange themselves, which, in turn, affects how they perceive interaction quality with the robot [33]. The robot's full body rotation was found to be more effective than head rotation only.

The decoration of telepresence robots also influences local users' perceptions of remote users [44, 59]. After a robot-mediated interaction, local participants perceived the remote user of the telepresence robot as more similar to themselves and as more trustworthy when the system has been decorated by the participant compared to when the system was undecorated [44]. Decorating the telepresence robot with an assigned group color created a sense of membership between the local and remote users. These findings all suggest that nonverbal processes involving telepresence robots affect how partners come to view one another after a mediated interaction. It may be possible to enhance relationship building via telepresence robots through further attention to issues of spatial configuration and embodiment.

Mimicry in interpersonal communication

In face-to-face interpersonal communication, a number of embodied processes support affiliation. These processes can operate even without our conscious awareness, such as when we automatically imitate the body postures, mannerisms, and facial expressions of our partners [10, 24]. Nonconscious mimicry plays a key role in building social relationships, with tendencies toward mimicry increasing when partners are more concerned with the feelings of others, or seeking to enhance the closeness of their relationships with others [34]. Experimental studies have also shown that liking can increase when confederates deliberately mimic the behavior of their communication partners, typically without the partners ever becoming aware of the imitation [9]. These effects have been replicated for a number of behaviors including facerubbing, foot-shaking, playing with an object, body orientation, or style of spoken language (e.g., particular phrases and tone of voice) [10, 22, 41, 47, 62]. One mechanism of these effects is perceived similarity. When partners engage in greater mimicry, they are viewed as being more similar to oneself, which increases rapport [60]. As automatic mimicry allows individuals to successfully build social relationships, a tendency toward this behavior would have eventually become widespread in an evolutionary context [34].

While our physical apparatus for automatic mimicry emerged in the context of face-to-face interaction, some recent work suggests that it is possible to achieve mimicry in agent-based communication. Bailenson and Yee [5] conducted an experiment in which participants, representing themselves through avatars in a virtual environment, communicated with computer-based agents. These agents, also represented as human characters, were programmed either to automatically replicate the head movements of participants (i.e., mimicry condition), to move a similar amount without mimicking to the participants' orientation (i.e., random movement condition), or not to move (i.e., static condition) during the interaction. Results indicated that mimicry increased participants' ratings of the agents' positive qualities and persuasiveness more than other conditions. Given these findings, some have proposed that the principles of mimicry should be applied more broadly to design of human-like agents and robots in order to improve user experience [37].

While some prior work has explored interpersonal processes in robot-mediated communication, physical mimicry remains unexplored. For telepresence robots to become broadly acceptable in distance communication, including for informal communication, it is important to understand how telepresence robots can support liking and rapport between partners. Mimicry plays an important role in such processes. Prior work has shown that linguistic mimicry can operate in mediated communication, enhancing liking [21, 47]. Historically, however, mediated communication has not been conducive to perceiving and replicating partners' physical movements. By combining a real-time video feed with an embodied presence, telepresence robots may overcome this impoverishment, enabling operators to perceive the subtle movements of their partners and physically imitate them.

In this paper, we aim to better understand how movements of a telepresence robot influence perceived affiliation between local and remote users and to examine how individual differences play roles in such effects. We present a laboratory study where participants interact with a remote confederate using a telepresence robot in a conversational task (Figure 1).

Individual differences

Research also indicates that the effects of mimicry correspond to individuals' social orientations. Snyder [52] introduced the theory of self-monitoring to describe trait differences in the modulation of expressive behavior to achieve social goals. Self-monitoring refers to the extent to which an individual adjusts his or her behavior to situational demands [52]. Whereas low self-monitors present themselves in the same way regardless of social context, high self-monitors act as a kind of social chameleons, habitually monitoring their environments in order to tailor their performances of self [52]. Self-monitoring therefore relies on a number of preconditions: sensitivity to social cues, ability to infer contextually–specific social norms, and capacity and inclination to manipulate one's expressive behavior accordingly [16, 52]. Self-monitoring can therefore be highly relevant to perceiving and interpreting nonverbal behavior such as movement.

HYPOTHESES

To better understand the effects of different forms of movement in robot-mediated communication and the role of individual differences, we formulated two research questions and four hypotheses regarding local users' perceptions of remote users, drawing on prior research in face-to-face and computer-mediated communication.

Does movement matter?

Movement and embodied presence are key features of telepresence robots that distinguish them from videoconferencing systems [43]. Prior research in both face-to-face and mediated-communication suggests that these features predict rapport, including judgments of attractiveness, similarity, and closeness of partners [1, 29], and this even operates when movements are subtle or uncoordinated to the partner [39]. Thus, we first make the following prediction to examine the effect of robot movement regardless of its coordination to the partner:

H1. Local users will perceive greater affiliation with a remote user that communicates with them via a telepresence robot that displays movement cues than one that is stationary.

While we expect movement in general to positively shape affiliation in robot-mediated communication, literature on face-to-face, agent-based, and mediated communication suggest that, when movements of communication partners are aligned, e.g., through *mimicry* [5, 60, 32], these communicative outcomes are even stronger. Thus, we posit the following hypothesis.

H2. Local users will perceive greater affiliation with remote users who communicate with them via a telepresence robot that mimics their behavior than a telepresence robot that moves but does not mimic.

Do individual differences matter?

We further examine how the predicted effects of robot movements articulated in H1 and H2 vary across individuals, particularly across personality and sex-based individual characteristics. According to literature on personality-based differences, particularly self-monitoring [16, 52], high self-monitors attend and respond to subtle movement cues including mimicry more than low self-monitors do. Thus, we propose that self-monitoring also plays a role in nonverbal processes in the robot-mediated communication context.

H3. The effects of robot movement on local users' affiliation with remote users will depend on local users' level of self-monitoring.

Another key individual characteristic that shapes face-to-face [14] and mediated [23] communication is gender. Some prior work has found strong gender effects in the production [12] and perception [64] of mimicry, which we also expect to see in robot-mediated communication. Studies also indicate that males and females perceive technologies differently [44, 56], and therefore may respond differently to robot-mediated movement. Thus, while we predict user gender to play a role in perceptions of remote partners, we do not have sufficient evidence to predict a particular direction for the effect.

H4. The effects of robot movement on local users' affiliation with remote users will depend on user gender.

METHOD

To test the hypotheses described above, we designed a laboratory study that compared participants' affiliation with and perceptions of a remote confederate who communicates with them via a telepresence robot across several styles of movement. The paragraphs below detail our participants, study design, procedure, manipulation, measures, and analysis.

Participants

A total of 36 participants (18 male, 18 female), stratified by gender within each condition, took part in our study. All participants were recruited from the university of Wisconsin–Madison campus. Participants were aged 18–44 years ($M = 22.83, SD = 5.82$). Participants were compensated $5 USD for their participation. The UW–Madison Institutional Review Board (IRB) approved this research.

Study Design

Following the movement manipulations used by Bailenson and Yee [5], we examine the effects of interactions where the telepresence robot (1) mimics the participant's orientation, (2) displays random movements not coordinated to the participant, or (3) is stationary. The experiment features a 3 × 1 (movement: mimicry, random, vs. static) between-participants design in which a participant completed a "get-to-know-you" conversation task with a female confederate (the "communicating confederate") over a telepresence robot. Participants were told that the confederate was another participant assigned to the same time slot. To control for the large interpersonal variability in factors eliciting social processes, such as physical attractiveness and communication style, the same confederate communicated with participants in all three conditions. To enable the communicating confederate to focus on interacting with the participant and to minimize interference between the interaction task and the task of controlling the robot, the telepresence robot was operated by another female experimenter (the "operating experimenter") who sat at a separate monitor next to the communicating confederate and was out of sight of the participant. A Beam Pro system, a professional-grade telepresence robot designed and manufactured by Suitable Technologies,[1] was used for the experiment.

Procedure

Participants were invited to the lab and told that the purpose of the study was to examine how people interact with a stranger, another participant, over a telepresence robot system. The participants were told that the other participant was located in another building across campus and would use the control interface for the telepresence system to communicate with him or her. Then, they signed a consent form and provided answers to a pre-experiment questionnaire including personality measures. For the experimental task, we used a "get-to-know-you" exercise [19] in which participants were instructed to get to know their partner (the communicating confederate, whom they were led to believe was another participant) in five minutes and to talk about anything they wanted. The telepresence robot entered the room to begin the interaction. After the interaction, the telepresence robot left the room, and participant provided answers to a post-experiment questionnaire about the interaction and debriefed.

[1] Suitable Technologies Beam Pro: http://suitabletech.com

Manipulation

Three study conditions varied the movement of the robot during the get-to-know-you interaction. The operating experimenter either (1) did not move the telepresence robot ("static" condition) or moved it by referencing (2) a live-streamed video of the current participant ("mimicry" condition) or (3) a video recording of the former participant in the mimicry condition ("random movement" condition), as was done by Bailenson and Yee [5]. More specifically, in the static condition, the robot remained stationary during the interaction beyond entering and leaving the room. In the remaining two conditions, the operating confederate moved the robot left and right at a speed of 1.5 mph using the keyboard commands "left" and "right." In the mimicry condition, the operating experimenter moved the robot to mirror the participants' upper body posture and movement, capturing both orientation and speed. That is, if the participant moved his/her head or upper body to the right, the operating experimenter would "mirror" this behavior by turning the robot to the left. Finally, a third, random movement condition replicated the same level of movement as the mimicry condition but in a way that was not aligned with the movement of the participant. Instead, the robot mimicked the recorded movement of a previous participant. Specifically, the operating confederate responded to movement cues from a video recording of the prior participant in the mimicry condition, whereas the communicating confederate saw live video feed of the current participant.

In the two movement conditions, the telepresence robot mimicked the participant's movements with an approximate average delay of 500 ms the sources of which included the response time of the operating confederate, network latency, and inherent delays in robot actuation. Across all three conditions, the robot maintained an approximate distance of five feet from the participant, consistent with prior research establishing it as a comfortable conversational distance [15]. While participants were not given any instruction regarding movement, they rarely moved forward or backward beyond a couple inches, and this distance was maintained across the interactions. Participants instead moved their arms, head, and body orientation, which the telepresence robot imitated by rotating to the left or right. During the interactions, the communicating confederate was instructed not to change her body orientation or to move her arms into the video frame (which could have revealed that she was not controlling the movements of the robot). While her facial expressions and conversation topics were not strictly controlled, she was blind to study condition, and we expect variability in her movements and conversation topics to spread randomly across the conditions.

Measures

To measure local participants' affiliation with and perceptions of the remote confederate and their individual characteristics, we used following measures.

Perceptions of the Remote Partner

Drawing on literature on interpersonal communication, we operationalize rapport with and affiliation toward the remote user as involving (1) perceived *similarity* to and (2) interpersonal *closeness* felt toward the remote confederate [42, 53]. To measure participants' perception of similarity toward a remote user, we used a well-validated Perceived Homophily scale developed by McCroskey [38]. The scale is one of the most widely used measures of perceived similarity. It consists of nine items, and each item was measured on a seven-point scale (1 = strongly disagree, 7 = strongly agree) (Cronbach's $\alpha = 0.72$). The negative items were reversed and summed across the responses ($M = 39.50$, $SD = 6.59$). To measure participants' feelings of closeness toward the remote user, we adopted one item from the Inclusion of Other in the Self (IOS) scale [3]. The item asks participants to rate how close they felt to their partner and provides Venn-like diagrams depicting five degrees of overlap between two circles [61]. The item is widely used to measure perceived closeness ($M = 2.75$, $SD = 1.20$). Three open-ended questions prompted participants to elaborate on aspects of the interaction that they liked and did not like and provide any additional comments about their experience.

Individual Characteristics

Participants filled out a questionnaire measuring levels of *self-monitoring* in the initial survey, which was measured using the 25-item Self-Monitoring Scale developed by Snyder [52]. The original version of the scale used a true-false response scheme, which we modified into a Likert-type scale for psychometric purposes. After reversing negative items, we took the average of item responses ($M = 4.08, SD = 0.51$, Cronbach's $\alpha = 0.68$). The alpha coefficient reported by Snyder [51, 52] for the scale was $0.66 - 0.70$. Participants' familiarity with robots, $M = 3.58, SD = 1.00$, and comfort with videoconferencing, $M = 2.69, SD = 0.89$, were measured by two single items: "How familiar are you with robots?" and "How comfortable are you with videoconferencing?" using seven-point rating scales (1 = not at all, 7 = very much). At the end of the study, participants filled out a questionnaire asking demographic information including gender, age, and ethnicity.

Analyses

To test our hypotheses, we used analyses of variance (ANOVA) and analyses of covariance (ANCOVA). To test H1 and H2, we used the same ANOVA model with experimental manipulation as the only independent variable. For H3, we used an ANCOVA with experimental manipulation, self-monitoring, and their interaction as independent variables and perceived similarity and closeness as the dependent variables. Testing for H4 involved ANOVA with experimental manipulation, gender, and their interaction as independent variables and perceived similarity and closeness as the dependent variables. Our analysis employed Bonferroni correction to control for Type I errors in all contrast tests and pairwise comparisons (used in the testing of H1 and H2) and *post hoc* pairwise comparisons (used as exploratory analyses following the testing of H4).

RESULTS

Manipulation Check – We first conducted manipulation checks to establish that participants in mimicry and random movement conditions noticed higher levels of robot movement relative to the static condition. A one-way ANOVA was conducted to determine if participants in the mimicry and random movement conditions reported higher levels of movement in the robot compared to those in the static condition. Results showed that the movement manipulation had a significant effect on how much robot movement was reported by the participants, $F(2,33) = 4.83, p = 0.015$. As we expected, participants in the mimicry condition, $M = 4.17$, $SD = 1.75$, and the random movement condition, $M = 4.00$, $SD = 1.86$, reported higher levels of robot movement than those in the static condition, $M = 2.33$, $SD = 1.07$. Pairwise comparisons revealed that the difference between the mimicry and static conditions was statistically significant, $p = 0.025$, as was the difference between the random and static conditions, $p = 0.046$, but the difference between the mimicry and random conditions was not significant, which is expected since both conditions feature similar levels of movement.

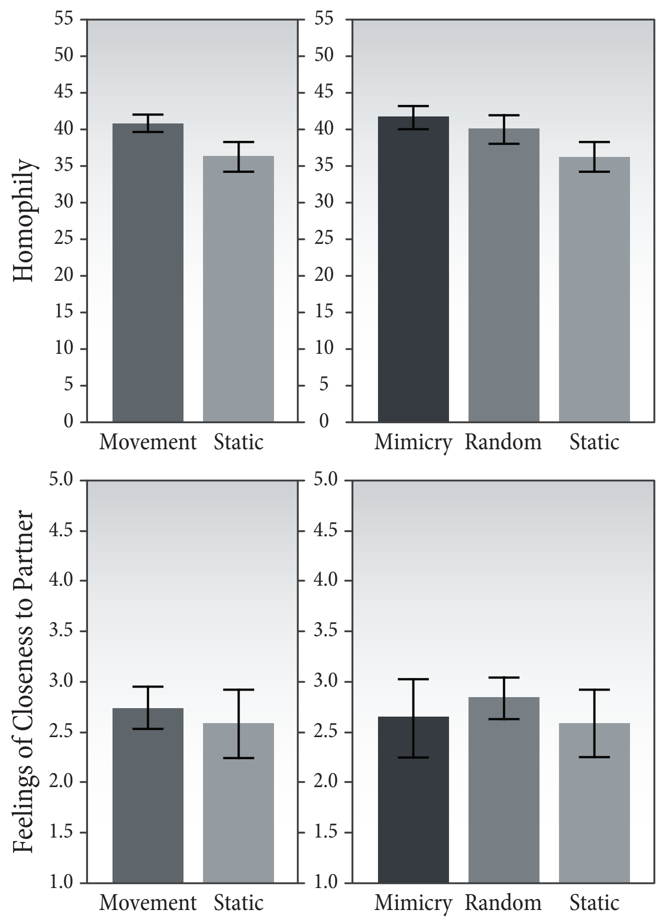

Figure 2. The effects of movement and movement type on measures of affiliation including homophily and feelings of closeness to partner. Our analysis shows that local users report greater homophily toward partners communicating through a robot that displays movement than they do toward partners communicating through a static robot. Error bars represent standard error of the mean.

Testing for H1 and H2– H1 predicted that participants would report increased affiliation with remote users, specifically rating them to be closer and more similar to themselves, when they communicated with them using a telepresence robot that moved rather than a static robot. In H2, we predicted that participants would rate remote users to be closer and more similar to themselves when they communicated with them using a telepresence robot that mimicked their body orientations than a robot that displayed random movements. To test H1 and H2, we conducted a one-way ANOVA followed by planned contrasts between movement (random and mimicry) and static conditions for H1 and between random and mimicry conditions for H2. Additionally, we report on pairwise comparisons between each individual movement condition and the static condition to provide a fuller picture of our data.

Shapiro-Wilk tests show that the data in each condition were normally distributed ($p > 0.05$); Levene's test showed no violation of homogeneity of variance in the data ($p > 0.05$). Results showed a significant effect of the robot movement on participants' perceived similarity, $F(2,33) = 3.50$, $p = 0.042$, $\eta^2 = 0.18$, but not on their perceived closeness, $F(2,30) = 0.16$, $p = 0.85$, $\eta^2 = 0.01$. Planned contrast tests showed that participants in the movement conditions (mimicry and random conditions), $M = 41.33$, $SD = 6.06$, reported higher levels of similarity toward the remote user than did participants in the static condition, $M = 35.83$, $SD = 6.28$, $p = 0.017$, providing partial support for H1. However, we found no support for H2; there was no statistically significant difference between the mimicry, $M = 42.33$, and random conditions, 40.33, in perceived similarity, $p > 0.05$. Additional comparisons showed that the difference between the mimicry and static condition was statistically significant, $p = 0.014$, and the difference between the random and mimicry conditions was marginally significant, $p = 0.083$. Figure 2 illustrates data used for testing H1 and H2 on the graphs on the left and right, respectively.

Testing for H3 – H3 predicted that self-monitoring would moderate the effects of robot movement on local users' perceptions of the remote user. To test H3, we conducted an ANCOVA with experimental conditions, self-monitoring, and the interaction between them as independent variables and perceived similarity and closeness as dependent variables. Levene's test of homogeneity of variances showed no violation of homogeneity of variance in the data ($p > 0.05$). The independence of self-monitoring and the experimental conditions was assumed, $F(2,33) = 1.46$, $p > 0.05$. Our analysis found partial support for this hypothesis; there was a significant interaction effect between the movement manipulation and self-monitoring on perceived similarity, $F(2,30) = 4.22$, $p = 0.024$, $\eta^2 = 0.22$, but not on perceived closeness to the partner, $F(2,30) = 0.80$, $p > 0.05$, $\eta^2 = 0.05$. No significant main effect of self-monitoring on perceived similarity was observed, $F(1,30) = 1.42$, $p > 0.05$. Our analysis showed a positive association between self-monitoring and perceived similarity in the mimicry condition, $B = 3.63$, $SE = 3.15$, and in the random movement condition, $B = 8.43$, $SE = 4.77$, but a negative one in the static condition, $B = -5.05$, $SE = 3.15$. While the slopes for the mimicry and random movement conditions did not significantly differ, $p > 0.05$, the slopes for the mimicry and static conditions were marginally different, $p = 0.072$, and the slopes for the random movement and static conditions were significantly different, $p = 0.008$. Figure 3 shows perceived similarity measurements across the three movement conditions and self-monitoring levels.

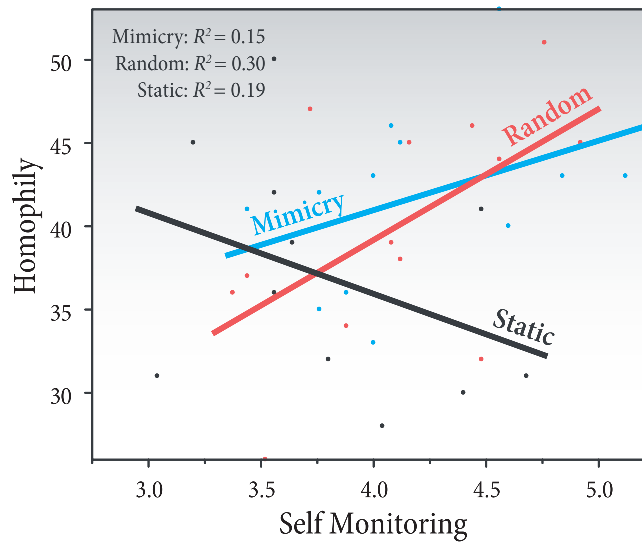

Figure 3. The effects of individual differences, particularly self monitoring, on perceived homophily across the different movement types. We found that high self-monitors rated greater affiliation in the two movement conditions and reduced affiliation in the static condition.

Testing for H4 – Finally, H4 predicted that gender would moderate the effects of robot movement on local users' perceptions of the remote user. To test the moderating effect of gender, we conducted an ANOVA with the movement manipulation, gender, and interaction between the movement manipulation

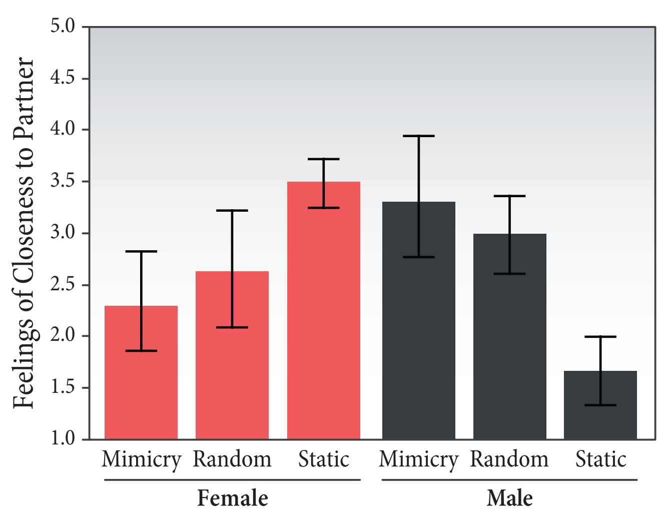

Figure 4. The effects of the movement manipulation on feelings of closeness across females and males. Our analysis found a significant interaction effect between movement type and participant gender, indicating that movement affects how females and males affiliate themselves with partners differently. Error bars represent standard error of the mean.

and gender as independent variables and perceived similarity and closeness as dependent variables, respectively. Levene's test of homogeneity of variances showed no violation of homogeneity of variance in the data ($p > 0.05$). Our analysis found a significant interaction effect between the movement manipulation and gender on perceived closeness, $F(2,30) = 5.36$, $p = 0.010$, $\eta^2 = 0.26$ (Figure 4), but not on perceived similarity, $F(2,30) = 2.89$, $p > 0.05$, $\eta^2 = 0.16$, providing partial support for H4. We further inspected reported levels of perceived closeness across conditions for each gender group using *post hoc* analysis. For males, participants' perceived closeness scores (reported as mean $\pm$ standard deviation) in the mimicry condition (3.33 ± 1.51) were higher than those in the random movement condition (3.00 ± 0.89), which were higher than their scores in the static condition (1.67 ± 0.82). Females' ratings of perceived closeness showed the opposite pattern; their ratings in the mimicry condition (2.33 ± 1.21) were lower than those in the random movement condition (2.67 ± 1.37), which were lower than their ratings in the static condition (3.50 ± 0.55). *Post hoc* pairwise comparisons showed that differences between the movement conditions were not statistically significant for either gender group.

Qualitative Analyses – Review of open-ended items included in the exit survey revealed various specific responses to and interpretations of the robot's movement. While most participants did not remark on the movement, those who did ($n = 8$) typically had positive responses. In the mimicry condition, one participant commented on the naturalism of the movement, writing that the movement of the robot "made it seem more human in the way that humans move slightly when they talk... The robot and screen seemed to embody a human without hands/arms." Another noted that the confederate seemed able to exert agency through movement: "she maintained control of the robot and could rotate and move herself if needed." Two participants in the static condition as well as one participant in the random movement condition remarked on the robot's lack of movement as a disadvantage in the interaction.

Some negative aspects of the robot's movement and positioning were also reported in open-ended responses. One participant in the random movement condition wrote, "sometimes the machine wasn't directly facing me which made it awkward." Another participant in the random movement condition noted that he would have liked to move and gesture more himself but was worried that he wouldn't remain in the robot's field of view. Finally, several participants indicated that they would have preferred to interact while seated.

DISCUSSION

Telepresence robots provide an opportunity to replicate an important aspect of face-to-face communication—physical movement and mimicry—while communicating from a distance. Our results suggest that both mimicry and random movement can be accomplished via a telepresence robot and can affect perceptions of the communication partner; however, this effect depends on individuals' social orientations and gender. Specifically, those more inclined to adapt behaviors to the social context, high self-monitors, viewed their partners as being more similar in both movement conditions relative to the static condition. Males felt closer to their partner in the movement conditions relative to the static condition, whereas in contrast, females felt closer to their partner in the static condition relative to the movement conditions. Broadly, our findings suggest that, as in face-to-face interactions, individual differences shape the effects of nonverbal processes in robot-mediated communication.

This research has theoretical and practical implications on several fronts. First, it offers insight into whether the effects of nonverbal processes in interpersonal communication persist when communication is mediated through telepresence robots. Second, by considering telepresence robots' movements in an informal communication setting, it advances the robot-mediated communication literature, which, to date, has mostly been applied to task-related, collaborative scenarios. Lastly, it offers practical implications for designing communication technologies. These contributions are discussed below.

MOVEMENT MATTERS

Our findings showed that local users felt more similar to remote users when communicating with them via a moving telepresence robot than via a stationary robot. It is likely that the robot's movement enhanced the presence of the remote user so that people felt more engaged in the movement conditions [39, 50]. Future work may measure perceived presence to examine a potential mediating effect. While we found no significant differences between the mimicry and random movement conditions in perceived similarity toward the remote user, pairwise comparisons also showed that only mimicry achieved a statistically significant difference from the static condition on the same outcome. These results suggest that movement matters, especially when movement mimics the partner's body orientation. This finding is similar to prior work in which an embodied agent mimicking the head movements of participants was reported as more persuasive and likable than an agent utilizing recorded movements [5]. However, the telepresence robots' mimicking behavior through the orientation of its frame may not be as high-fidelity a cue as an embodied agent's head movements, and true mimicry is hard to achieve through the bodily affordances of the robot, as would explain the limited differences between our two movement conditions. The telepresence robot's movements are limited because its head and body are connected into a single frame and do not move independently while the virtual agent can mimic three dimensions of the participants' head movements.

Participants in the movement conditions felt more similarity with a remote user than participants in the static condition, and perceived similarity is known to be one of the strong predictors of liking toward the communicative partner [2, 18, 25]. It is possible that participants perceived the robot's subtle motions, regardless of coordination, as reflecting engagement and responsiveness in the interaction. Future research should develop a more detailed mapping between the space of possible robot movements and how they shape local users' perceptions of the remote user. Such investigation will require extending the investigation to other telepresence robot platforms with additional affordances for bodily expression.

Individual Differences Matter

One of the important goals of this study was to examine the role of individual differences in building rapport in conjunction with the movements of a telepresence robot. Our study found differences in the effects of movement related to self-monitoring and gender, both of which may influence participants' orientation toward building relationships with their partner. We observed the effect of robot movements on perceived similarity is moderated by participants' level of self-monitoring. In both movement conditions, high self-monitors perceived more similarity with a remote user than low self-monitors, although this increase in similarity was significant only in the random movement condition. In the static condition, similarity ratings significantly decreased as levels of self-monitoring increased. Consistent with prior work, this finding suggests that high self-monitors pay close attention to nonverbal processes in forming impressions of their partners. In the absence of the robot's movement, high self-monitors felt less similar to their partner than low self-monitors did, as underlined by negative relationship between perceived similarity and self-monitoring observed in the data from the static condition. It is unclear based on our findings whether the robot's movement itself led to higher perceived homophily among high self-monitors or whether high self-monitors actually accommodated to the robot's movement by imitating it themselves, generating homophily through their own imitation. It will be essential for future research to further explore the mechanisms of how self-monitoring shapes perceptions of movement in robot-mediated communication. In this study, we did not find an interaction effect between self-monitoring and the experimental conditions on perceived closeness. Perhaps the robots' movements can shape the perception of similarity among high self-monitors but a five-minute interaction is too short for them to establish closeness.

The present study also found a moderating effect of gender on perceived closeness. While some prior research has suggested that females have an advantage in interpreting nonverbal behavior [8, 20], our results show that, in fact, it was only among men that robot movement amplified feelings of closeness to the remote partner. For women, feeling of closeness was lower in the movement conditions than in the static condition, although these differences did not achieve statistical significance. Additional processes may therefore be at play. First, given that we used the same female confederate in all interactions, it is possible that our results reflect that same-gender or mixed-gender dyads were formed for female and male participants, respectively. The interpretation of the robot's movement may change depending on the gender composition of the dyad, with movement perhaps suggesting romantic interest from an opposite sex partner, as has been found in prior research in a face-to-face context [27]. Another possibility is that females tried to focus on the actual person operating the robot (i.e., through the video feed) and found the relatively unnatural movements of the robot distracting [49], whereas males may have been more attentive to the behaviors conveyed by the embodiment. The potential mechanisms of the observed gender effect should be tested in future research. For instance, adding a male confederate would also allow us to investigate the hypothesis that males' positive response to mimicry is specific to the context of a gender-mixed dyad. The moderating effect of gender, however, was not observed on perceived similarity. Across females and males, participants felt more similarity with a remote user when communicating over a moving robot compared to when communicating over a static robot. Perhaps similarity is a more gender-neutral concept compared to closeness to the partner which could be more directly associated with interpersonal attraction.

Design implications

Our findings suggest that an embodied telepresence robot's physical movements have a positive influence on interpersonal outcomes. According to our findings, whether the robot moved in accordance with the local user or not did not make a big difference. This finding suggests that enabling even general, uncoordinated movements during interactions can enhance interpersonal processes. Such subtle movements can also be easily automated and utilized in interaction without any burden on the remote user. Additionally, while this study did not find an effect specific to mimicry, we speculate that this is at least partly because of the limited motions available with the current telepresence robot systems. We therefore highlight the need for designing telepresence robot systems with a broader range of bodily cues and capabilities for movement. For example, enabling independent head movements can avoid whole body orientations that may be distracting during interactions.

Limitations

As with any single experiment, our study has several limitations. First, while we used a state-of-the-art, high-end telepresence robot system designed for professional use, the system had a limited repertoire of movements (orienting or moving forward, backward, left, or right). These possible movements can only roughly approximate the substantially richer and subtler human body motions (e.g., shaking a hand, shrugging, fidgeting, leaning). Furthermore, the delay between participant movements and the robot movements, introduced by a combination of operator response time, network latency, and robot actuation delays, may have affected perceptions of the mimicked movement. However, our qualitative observations suggest that this delay was not noticeably different from delays and variability that naturally occur in face-to-face nonverbal mimicry. Nonetheless, even given this limited repertoire and our small sample size, we were able to identify effects of movement on similarity and closeness. A second limitation of this study is that, during the interactions, the communicating confederate viewed a video feed of the participant from the perspective of the camera mounted on the telepresence robot, and therefore she could have herself been influenced by the robot's movement. With that said, the robot's motions tended to be subtle and, given that the operating experimenter moved the robot, the conditions were experienced very similarly by the communicating confederate, limiting the possibility of experimenter effects.

Future Directions

Our results suggest promising areas for future research. First, our study highlights the important role individual differences play in perceptions of movement in robot-mediated communication. We also know from prior mimicry literature that orientation to relationship building can be affected by social roles and situational factors. For instance, individuals are inclined to engage in mimicry when interacting with higher status individuals since they may have more to gain through creating positive impressions [4]. Research also suggests that equivocal situations call for availability of a greater range of cues [11], as do situations involving exchange of affective information [28, 48]. Mimicry might have a particularly important role for interactions that are even more affectively charged than those presented here, such as in interactions with close others. Future research is necessary to understand how the nonverbal movements of embodied communication technologies shape the perception of others in different relational communication contexts.

While we found encouraging effects of embodied movement on perceptions of the partner, our study design did not compare these effects to those of nonverbal behaviors found in face-to-face communication. Relatedly, we also do not know, based on our study, the effects that on-camera mimicry (e.g., of facial expressions) might have had on the studied processes. Because on-camera mimicry should have been consistent across conditions, we only know that embodied movement had additional, independent effects. Future research may examine the relative strength of movement and mimicry via the video feed versus the embodied movements of the telepresence robot and may compare these effects to face-to-face mimicry.

CONCLUSION

Nonverbal behaviors are essential cues that shape interpersonal communication, and their importance in computer-mediated communication and robot-mediated communication has been highlighted by prior research. The results from this study advance our understanding the role movement and mimicry play in robot-mediated communication. The present study shows that individuals build positive perceptions of a distant partner communicating through a telepresence robot, which makes slight movements during the interaction, and these effects are similar whether or not movements mimic the partner's body orientation. Furthermore effects of movement are moderated by individual characteristics. We conclude that even with limited cues available with the present telepresence robot systems, nonverbal behaviors play an important role in robot-mediated communication. Our study sheds light on our theoretical understanding of nonverbal processes via telepresence robots and offers implications for the future design of communication technologies through a more detailed understanding of user experience with movement as a design element.

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