My Telepresence, My Culture? An Intercultural Investigation of Telepresence Robot Operators' Interpersonal Distance Behaviors

Solace Shen
Cornell University
Ithaca, NY, USA
solace.shen@cornell.edu

Hamish Tennent
Cornell University
Ithaca, NY, USA
ht353@cornell.edu

Houston Claure
Cornell University
Ithaca, NY, USA
hbc35@cornell.edu

Malte Jung
Cornell University
Ithaca, NY, USA
mfj28@cornell.edu

ABSTRACT
Interpersonal distance behaviors can vary significantly across countries and impact human social interaction. Do these cross-cultural differences play out when one of the interaction partners participates through a teleoperated robot? Emerging research shows that when being approached by a robot, people tend to hold similar cultural preferences as they would for an approaching human. However, no work yet has investigated this question from a robot teleoperator's perspective. Toward answering this, we conducted an online study ($N = 774$) using a novel simulation paradigm across two countries (U.S. and India). Results show that in the role of a telepresence robot operator, participants exhibited cross-cultural differences in interpersonal distance behavior in line with human-human proxemic research, indicating that culture-specific distance behavior can manifest in the way a robot operator controls a robot. We discuss implications for designers who seek to automate path planning and navigation for teleoperated robots.

ACM Classification Keywords
H.4.3 Information Systems Applications: Communications Applications-Computer conferencing, teleconferencing, and videoconferencing; H.5.m Information interfaces and presentation (e.g., HCI): Miscellaneous.

Author Keywords
Robot-mediated communication; telepresence robots; robotic telepresence systems; proxemics; interpersonal distance; cross-cultural; human-robot interaction.

CHI 2018, April 21–26, 2018, Montreal, QC, Canada

ISBN 978-1-4503-5620-6/18/04...$15.00
DOI: https://doi.org/10.1145/3173574.3173625

INTRODUCTION
Interpersonal distance behavior, the amount of space people maintain between themselves and others, is an important category of nonverbal behaviors [15, 27]. These behaviors can implicitly communicate power, dominance, and status, as well as social and emotional closeness [10, 28, 29, 52]. Violating interpersonal distance norms can elicit negative emotions with potentially detrimental consequences for the interaction [16]. For example, several studies have found increased levels of anxiety upon the violation of interpersonal space [7, 16]. A study by Heston [30] also found that a confederate approaching was seen as less sociable when personal space was violated.

Norms regarding the appropriateness of distance behaviors vary across national cultures [3, 22, 41]. Such cross-cultural differences in nonverbal communication can often be misinterpreted and lead to interpersonal misunderstanding, anxiety, and poor interaction outcomes [1, 25, 59, 67]. As groups and teams become increasingly multicultural, understanding intercultural nonverbal communication has increasingly gained prominence as a research area (e.g., [14, 40, 51]). Would cultural differences in nonverbal communication manifest when one of the interaction partners is not communicating through their own body, but the body of a robot? If so, how would they manifest? These scenarios are increasingly played out as the use of telepresence robots become more prevalent.

Social interaction with contemporary telepresence robots can be characterized as interaction between local users and remote users (robot teleoperators) through embodied, mobile videoconferencing such as the BeamPro seen in Figure 1. Understanding whether and how nuanced cultural differences in interpersonal distance behaviors manifest in telepresence robot mediated interactions is timely, as mobile robotic telepresence technology has recently reached a tipping point in affordability and usability in the consumer market. As a result, telepresence robots from companies such as Beam and Double Robotics are now widely used in general work contexts [46, 62], at

Figure 1: BeamPro telepresence robot, ©Suitable Technologies. Image used with permission from the Suitable Technologies Press Kit [70].

home [71], and in patient care [8]. As telepresence robots are increasingly used to support interactions across distance and culture, it is important to gain a better understanding of how they may influence social interaction in general, and intercultural interaction specifically.

Emerging research has shown that nonverbal cues from telepresence robots, such as height [49], head motion [56], and turning of the body [19], can affect perceptions of social interaction for both the local users and the remote operators. In terms of human-robot distancing, there is initial evidence that when being approached by a robot, people tend to hold similar cultural preferences as they would for an approaching human [36]. However, no work so far has investigated this question from the perspective of a robot teleoperator approaching a human. Given the delay between teleoperator input and robot execution, and the limitations of the robot's physical body, it is an open question whether the nuanced behavioral tendencies of the teleoperator (e.g., interpersonal distance preference) would transmit through the way an intermediary robot is controlled. In other words, would such culturally relevant behavioral conventions of teleoperators transmit through the mediation of the telepresence technology? Gaining an understanding of distance behavior through teleoperation is particularly relevant as these behaviors can manifest not only in standard telepresence robots, but also in any robot that can be teleoperated in an interpersonal context (e.g., a teleoperated security robot that patrols a crowded mall, a teleoperated hospital robot that transfers patients), even those robots that do not offer a video representation of the operator.

Toward answering the open question of whether a robot teleoperator's behavioral tendencies are transmitted through a teleoperated robot, we present an online study using a novel simulation paradigm that investigated intercultural differences in the interpersonal distance behaviors of telepresence robot operators across two countries (U.S. and India). We chose the U.S. and Indian cultures due to the availability of online participants, as well as expected behavioral differences in proxemics based on human-human proxemic research. We first review how culture relates to both human-human and human-robot interpersonal distance behavior and related work in human-robot interaction (HRI). We then describe the online study method and report the results. Our findings indicate that in the role of a telepresence robot operator, participants exhibited different interpersonal distance behaviors across the two cultures, and these differences are in line with findings from intercultural human-human proxemic research. Finally, we discuss the results and their implications for designers who seek to automate path planning and navigation for teleoperated robots and outline directions for future work.

This paper makes three important contributions. First, we provide initial evidence that remote operators of robots do exhibit culturally relevant behaviors through teleoperation. Second, we introduce a new robot teleoperation simulation paradigm that can facilitate future online investigations of remote robot operators' perspectives and behaviors. Third, we offer an important design insight for the automation of telepresence robot operation.

RELATED WORK

Culture and Proxemic Behavior

Culture has generally been defined as a system of shared attitudes, beliefs, values, manners and behaviors that are acquired and transmitted through interactions with other members [58, 61]. Over the past decades, a body of work has documented differences across cultures in social and behavioral norms (e.g., [31, 32]). In terms of nonverbal communication, studies have found cultural differences along eight nonverbal categories, including proxemics (i.e., use of space) [5].

Proxemic behaviors are also among the nonverbal behaviors that are associated with perceptions of power, dominance, and status. For instance, among samples of predominantly North American or Northern European individuals, smaller interpersonal distances were found to indicate perceptions of higher power, status, and credibility [2, 28]. Thus, understanding intercultural differences in nonverbal cues such as interpersonal distance behaviors has become increasingly important as intercultural collaboration becomes the new norm in our increasingly globalized society.

Of particular relevance to interpersonal distance is Hall's characterization of contact and non-contact cultures [27], also referred to as high and low-contact cultures. While there is no consensus, many scholars agree that higher contact cultures require smaller interpersonal distances (e.g., South Americans, Southern and Eastern Europeans), whereas lower contact cultures require larger interpersonal distances (e.g., North Americans, East Asians) [20, 54, 60, 68]. Andersen [6] further adds that warmer climates tend to produce high-contact cultures, and colder climates tend to produce low-contact cultures.

Within this framework, South Asians are expected to exhibit closer interpersonal distance behaviors than North Americans. Supporting this expectation, Watson [68] found that students from India and Pakistan sat closer to each other than students from America and Australia. Though in a recent study, Sorokowska et al. [57] found the opposite pattern, that Indian participants on average showed larger interpersonal distance preferences than the U.S. participants. These conflicting findings could reflect a change in interpersonal distance norms between the two countries over the past fifty years, or more likely, are due to a difference in methodology. The earlier Watson study used an observational interactive method between two participants, whereas the Sorokowska et al. study used a projective method in which participants were asked to mark distances on a graphic scale with figures representing people. While much easier to administer, projective techniques completely lack proprioceptive cues that would be present in actual interaction and thus may not reflect true behavioral tendencies. What can be gathered from these findings is that these two countries differ in their interpersonal distance norms.

It has also been argued that since culture influences one's chronic accessibility of independent vs. interdependent self-construals, cross-cultural differences such as those observed above are indirect evidence for the relation between self-construal and interpersonal distance behavior [33,63]. In other words, rather than culture, one's self-construal could be the more direct factor affecting one's interpersonal distance behavior. In a series of three studies, Holland et al. [33] showed that participants' independent vs. interdependent self-construals, whether activated through priming or chronic, predicted their interpersonal distance behaviors. However, Holland et al. did not include culture as a factor in their studies, thus the relationship between culture, self-construal, and proxemic behavior remains unclear.

Culture and Human-Robot Proxemic Behavior

Social interaction is no longer limited to those between humans and animals. On a daily basis, people across the world engage in interaction with artificial intelligent agents, whether it be Siri, Cortana, Alexa, or sometimes even robots (e.g., SoftBank's robot Pepper greeting customers at banks and airports). Unlike Siri, Cortana and Alexa, robots can exhibit embodied nonverbal behaviors. Would our current knowledge of intercultural nonverbal communication still be applicable when one of the interaction partners is a robot?

Research in HRI has shown that across platforms and functions, robots can elicit social responses from people in ways that are comparable to those elicited by other humans or animals [11, 23, 24]. Furthermore, a robot's non-verbal communication (e.g., gaze, gestures) can improve human-robot task collaboration by way of increasing understandability of the robot and reducing errors that can arise from miscommunication [12].

In terms of human-robot proxemics, studies have found that approach distances preferred by humans when interacting with a robot are within the ranges of comparable human-human social distances corresponding to either Hall's personal (0.45 to 1.2 m) or social (1.2 to 3.6 m) spatial zones [35,66]. Studies have also found that when interacting with a robot, people adhere to similar compensating behaviors observed in human-human proxemic interaction [45, 53]. That is, people attempt to maintain a desired degree of intimacy with a robot by compensatory changes in gaze and interpersonal distance (e.g., distancing themselves further from a robot that stares at them too much, or averting their gaze when a robot invades their personal space). Findings from across these studies suggest that some common rules of human-human proxemic behavior apply in human-robot interaction.

While there has been limited intercultural HRI work, the initial evidences show that there are differences in human-robot interaction across cultures. For example, Rau et al. [50] found in a study with Chinese and German participants that people evaluated a robot more positively when it behaved in ways aligning with their own cultural preferences. Comparable intercultural differences have also been found with regard to human-robot proxemics. For example, Eresha et al. [21] found that Arabs and Germans showed high vs. low contact differences in their expectations of the interpersonal distance between themselves and robots, such that Arab participants arrange themselves significantly closer to the robots than the German participants. Joosse et al. [36] also found in an online study that Chinese participants judged it appropriate for an approaching robot to get significantly closer to human than the U.S. participants.

The emerging research on intercultural human-robot proxemics to date, however, has only investigated the perspective of the human being approached by a robot. While this one-sided focus makes sense for interaction with autonomous robots, it is inadequate when it comes to interaction with teleoperated robots. As discussed above, social interaction with teleoperated robots is in essence robot-mediated interaction between local users and remote robot teleoperators. As such, the perspective of the robot teleoperator must also be considered. We sought to address this gap in the present study. It is possible that the limitations of current teleoperation visual and audio equipment may diminish the robot teleoperator's capacity to meaningfully express nonverbal cultural norms. Nevertheless, based on extant findings from intercultural proxemic research, and the observation that interpersonal proximity is among those nonverbal behaviors that are particularly difficult to change [26], we expect that robot teleoperators would exhibit interpersonal distance behavioral differences across cultures.

METHOD

We conducted a 2 (robot teleoperator culture) x 2 (local user culture) online study (N = 774) to investigate whether and how interpersonal distance behaviors of robot teleoperators differed across the U.S. and Indian cultures. Participants were approximately equally distributed across cells, ranging from 187 to 208 per cell. To facilitate the online collection of data, we leveraged the affordances of the telepresence robot control interface and developed a novel simulation paradigm that mirrored the experience of a robot teleoperator driving a

Figure 2: Screenshots of the practice video with a plant and the 4 video stimuli with U.S. and Indian actors.

telepresence robot forward. We created a series of interactive video stimuli featuring actors of each culture in the role of the local user. By interacting with the video stimuli through a simulated telepresence robot control interface, participants of each culture acted in the role of the robot teleoperator.

Interactive Video Stimuli Production

For the video stimuli, we created a series of four videos shot from the perspective of a telepresence robot approaching a local user in a hallway. To control for potential audio related confounding factors, all videos (including the practice video with a plant described below) are silent. We varied the local user in terms of culture and gender. Two of the videos featured U.S. local users, one female and one male, and the other two Indian local users, one female and one male. We chose to have 2 actors from each culture to increase the representativeness of stimuli, and varying between the genders also allowed us to control for the gender factor later in analyzing the data. We created an additional practice video replacing the local user with a plant in order to provide the participants with the opportunity to learn and familiarize themselves with interacting with the video stimuli through the simulation control interface. See Figures 2, 3 and the accompanying video for a screenshot of each video and a flow of the video sequence.

The videos were shot using a GoPro Hero 3+ mounted on a Suitable Technologies' BeamPro telepresence robot (seen in Figure 1). We chose to record the videos using a GoPro camera rather than the robot's onboard camera to gain a higher quality resolution for the raw videos for stimuli preparation, and to not be constrained into having the BeamPro's user interface present in the videos, thus making the stimuli effects more generalisable across different telepresence robot platforms.

The camera was mounted at a height of 1.46 m to match the eye level of the seated actors and was shot using the medium field-of-view settings (127 degrees) at 1080p resolution. All five videos were shot using the same 6.35 m (250") approach path, with the robot travelling at 3.59 km/h for the first 3.81 m (150"), and then slowing down to 1.85 km/h for the final 2.54 m (100"). The slow down point was chosen to demarcate the transition from Hall's [27] social zone for interaction with acquaintances to personal zone for interaction with good friends or family, which provided the participants with a more leisurely pace to feel the approach distance as well as allowed the interaction to seem more natural. All videos were cut at 9.26 seconds and began as soon as the robot began to move and was cut right before the robot reached the base of the table (about 0.48 m from the seated actors).

In the videos, actors were seated at a table and acted as if they were engaged in working on a laptop. To create a natural approach interaction, at the moment the robot slowed down, the actors looked up into the camera and greeted the remote robot operator by smiling and saying "hi." Then for the brief duration until the end of the video, they continued looking into the camera with no further social cues. All actors were selected to be approximately in the same age range, and of similar heights as to control the seated eye level at 1.46 m in all videos. The top of the plant used in the practice video was also at 1.46 m.

A counter was placed in white text in the bottom left hand corner of each video, which relayed the video frame numbers, all ranging from 0-556 (9.26 seconds @ 60 frames per second). Thus, each frame number is equivalent to an advance of 1.66 cm at the robot's initial faster speed, and 0.85 cm at the robot's later slower speed. The frame numbers were then used as a measure of the approach distance and converted to actual distance data.

Simulation Control Interface

The video stimuli were embedded into a web browser at a size of 850 x 400 pixels using the standard HTML5 video player. Two buttons were created using javascript to control the playing of the video and to reset it to the beginning. The "forward" button was designed to mimic the control interface of the telepresence robot. When participants pressed and held the "forward" button the video played, showing the robot's view moving forward as if the robot is moving forward along the path. When participants released the button the video stopped, making it appear as if the robot stopped also. This emulates the "forward" button function that is commonly found in the control interface of a telepresence robot, and provides a naturalistic way for participants to interact with the video that simulates the teleoperation of moving a robot forward. We

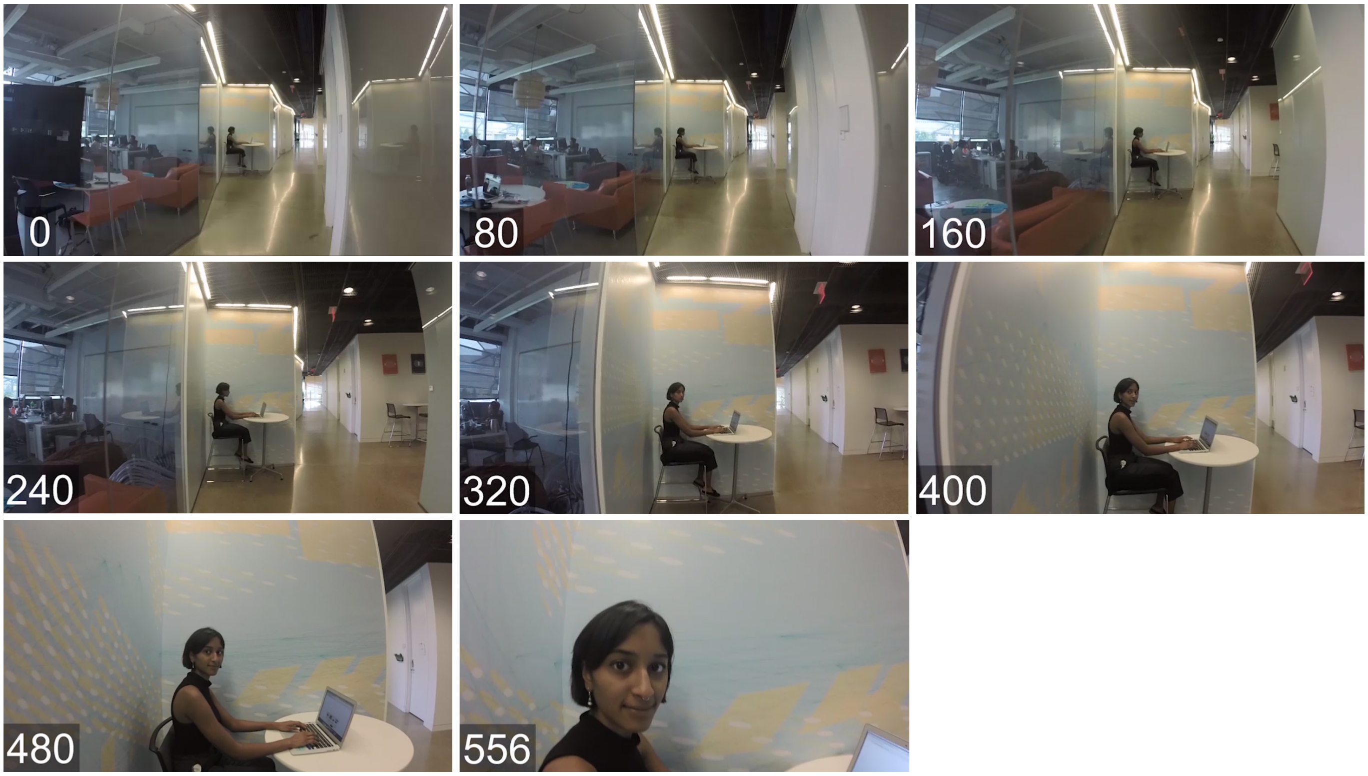


Figure 3: Video stimuli sequence.

also built a "reset" button that was only used with the practice video, so that participants could reset the video back to the beginning after having "moved" the robot. This allowed them to repeat the approach experience to familiarize themselves with the control interface. A screenshot of the simulation control interface can be seen in Figure 4.

Procedure and Measures

We created a survey using Qualtrics and conducted the experiment on Amazon Mechanical Turk (AMT). We chose AMT as a survey platform as it allows easy access to a large and diverse set of participants from both the U.S. and India. AMT responses have been shown to correlate well with laboratory data and allow for quick data collection and study iterations [18, 42].

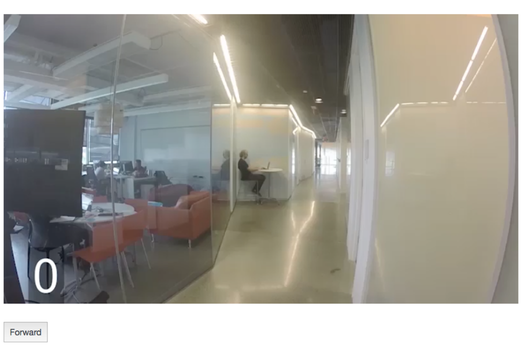


Figure 4: A screenshot of the simulation control interface, with the video frame counter in the bottom left corner (showing the number 0 in the image), and the "forward" button below the counter.

Participants were first asked to give informed consent. To ensure participants fully read through the instructions and consent form, we inserted a password into the bottom of the consent form that they would need to unlock the Qualtrics survey.

A brief description of what telepresence robots are and a picture of a telepresence robot were provided at the start of the survey. Participants were then asked to play a test video to ensure that their browsers were able to play the embedded HTML video that the survey would be using. We explicitly asked participants to play the video and to not progress unless they were able to.

Participants were then presented with a practice video to familiarize themselves with the simulation control interface. Embedded into the web page was the practice video featuring an approach sequence toward a houseplant in the same position as the actors in the video stimuli. This practice video also featured a "reset" button. As explained above, this was done so that participants could repeatedly practice until they felt comfortable with the controls. The functions of the buttons were explained, and participants were instructed to practice at least several times before proceeding. They were also in-

	Indian Participants (N = 400)	U.S. Participants (N = 374)
Female / male / non-binary %	45.75 / 52.50 / 1.75 %	49.47 / 49.47 / 1.07 %
Age	30.52 (SD = 6.75)	34.67 (SD = 10.33)
Height (cm)	164.33 (SD = 10.97)	172.22 (SD = 11.93)
Self-construal score	-0.61 (SD = 7.26)	7.63 (SD = 15.22)
Has used telepresence robot in the past	13.25%	0.27%

Table 1: Summary of participants' demographic and self-construal score means (standard deviations). Higher mean self-construal score indicates more accessible independent-self knowledge.

formed that they will not have the use of the "reset" button in the upcoming video task.

After the practice video, participants were presented with the experimental task. One video was randomly selected among the four stimuli, approximately balanced across participants' and actors' culture and gender. As explained earlier, participants could only interact with this key experimental video with the "forward" button, as we wanted to capture the participants' initial, intuitive judgements of the approach distance they felt comfortable. Participants were asked to think of themselves as the remote operator of a telepresence robot and the person in the video as a co-worker, and to move the robot forward toward the co-worker and stop at a point from the co-worker where they felt comfortable. Once stopped, participants were instructed to enter the counter number shown on the video (i.e., the frame number that corresponded to their approach distance) into the box blow.

After completing this key experimental task, participants were asked about their experience operating the telepresence robot in open ended text boxes, and if they have ever used a telepresence robot before. Participants were then asked to complete the 24-item Self-Construal Scale (with questions presented in randomized order) [55]. These responses allowed us to compute a self-construal score for each participant, such that the higher the score, the more independent the participant's self-construal was relative to interdependent. This provided us with a measure of participants' chronic self-construal in order to test the effect of self-construal on proxemic behavior. Finally, we collected demographic information from the participants regarding factors that have been found to influence interpersonal distance behavior: age, gender, height and cultural identification [13, 28, 34, 37, 47, 69].

Participants

Participants were AMT workers and were paid $1.00 for the estimated 10 minute survey. Workers were eligible to participate if they could read English and provided informed consent, were over the age of 18, resided in either the U.S. or India, and had a previous rating of 95% or higher using the AMT platform. Since participant culture is key to the present investigation, we used AMT's automatic IP filter to ensure that we only recruited participants from India and the U.S. Individuals who did not fully complete the survey and enter the completion code from Qualtrics into AMT were excluded from the dataset. In total, 1010 individuals completed the survey.

Three filters were used to further ensure data quality. First, as per previous AMT research recommendation [9, 17, 38], individuals that completed the survey in less than one-third of the average completion time were excluded (the mean completion time was 535.24 seconds). Second, individuals residing in the two countries that did not identify with the corresponding cultures were excluded to ensure that the dataset only consisted of individuals living in the U.S. that identified with U.S. culture and individuals living in India that identified with Indian culture. This was done to prevent confounding of the culture variable with potential bicultural effects (e.g., Indians that have acculturated to US culture to some degree and vice versa). Lastly, individuals who entered improper stop frame values were excluded. Two types of improper stop frame values were identified. The first type consisted of impossible values such as text strings and numbers outside of the range provided. The second type was identified after an examination of the dependent variable distribution, which revealed a bimodal distribution with a secondary smaller peak at 7, ranging from 0 to 9. This secondary peak is presumably the result of individuals who did not interact with the video at all and just entered the number 0, and individuals who gave the "forward" button only 1 click, which would advance the stop frame most often to 7 and within the 0-10 range. As such, it can be reasonably assumed that these responses were provided by individuals who did not understand/follow the instructions to hold down the "forward" button as instructed for both the practice and the stimulus videos. Our final sample included 774 participants. See Table 1 for a summary of participant demographic information.

RESULTS

Participants' stop frame numbers, the dependent variable, were first converted to actual approach distances in cm. Next, a log transformation was performed on the distance data to fit the assumptions of a linear model. A 2 (robot teleoperator culture) x 2 (local user culture) ANOVA with actor (local user) gender, and participant (teleoperator) gender, age, height, self-construal score, and past use of telepresence robot as control variables yielded main effects of robot teleoperator culture, $F(1, 763) = 8.32$, $p = .004$, partial $\eta^2 = .011$ and local user culture, $F(1, 763) = 10.31$, $p = .001$, partial $\eta^2 = .013$, and an interaction between the two, $F(1, 763) = 4.37$, $p = .037$, partial $\eta^2 = .006$. This significant interaction between robot teleoperator culture and local user culture was also found in the untransformed raw data, $F(1, 763) = 4.49$, $p = .034$, partial $\eta^2 = .006$.

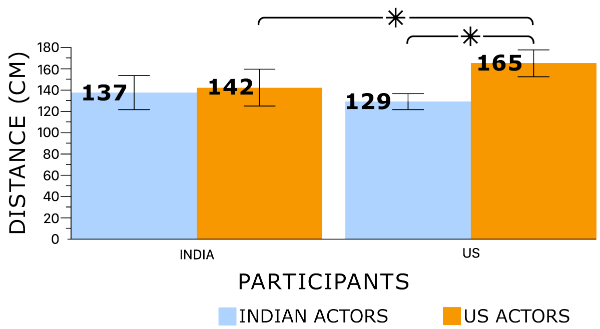


Figure 5: Raw mean approach distances. Each error bar is constructed using a 95% confidence interval of the mean.

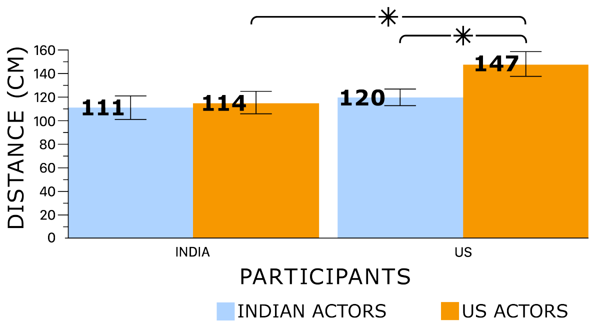


Figure 6: Back-transformed geometric mean approach distances. Each error bar is constructed using a 95% confidence interval of the mean.

Post hoc analyses using the Bonferroni correction revealed that U.S. participants stopped further away from the actor than Indian participants when approaching U.S. actors, $p < .001$, but not when approaching Indian actors, $p = .398$. Furthermore, while U.S. participants stopped further away from U.S. actors than from Indian actors, $p < .001$, Indian participants did not significantly differ in their approach distance toward either, $p = .419$. See Figure 5 for the raw and Figure 6 for the back-transformed geometric mean approach distances of each group, and Figure 7 for a visual comparison of the mean approach distances (using raw means).

All other main effects were non-significant, indicating that the control variables of actor (local user) gender, and participant (teleoperator) gender, age, height, self-construal score, and past use of telepresence robot had no significant effect on participants' approach distances over and above that of culture.

DISCUSSION

Results show that all mean approach distances are in line with previous cross-cultural human-robot proxemic research, and are within the ranges of comparable human-human social distances corresponding to either Hall' s personal (0.45 to 1.2 m) or social (1.2 to 3.6 m) spatial zones [27, 35, 66]. Furthermore, in the role of a telepresence robot operator, as expected, the U.S. participants, compared to the Indian participants, stopped further away from the U.S. actors in the role of a local user.

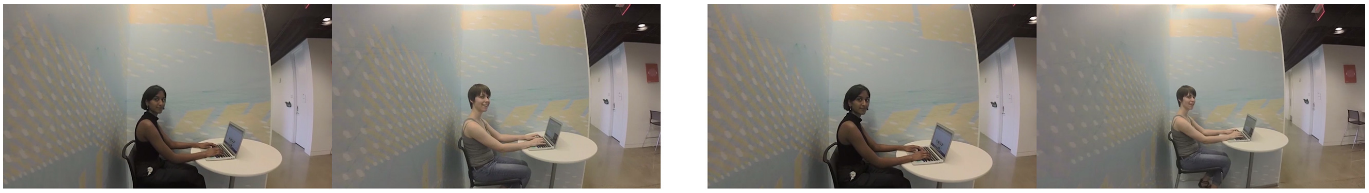
This cross-cultural pattern is in line with previous finding from human-human proxemic research between U.S. and India using an observational interactive method with two participants [68], but opposite of that was found with a projective method [57]. This suggests that the view offered by a typical telepresence robot control interface, unlike the projective techniques, offer sufficient proprioceptive cues for a teleoperator to judge and express proxemic information, at least in terms of interpersonal approach distance behaviors.

Literature indicates that interpersonal proximity is among those nonverbal behaviors that are particularly difficult to change [26]. Accordingly, we had expected that participants would exhibit proxemic behaviors consistently regardless of the local user actors' culture. It is curious that while the Indian participants did not significantly vary in their approach distances toward local user actors of either culture, the U.S. participants did. In other words, as expected, the U.S. participants, compared to the Indian participants, exhibited larger approach distances toward the U.S. local user actors, however, their approach distances toward the Indian local user actors were on par with those of the Indian participants. This interaction effect was unexpected.

One possible, tentative explanation for this result could be found in Molinsky's concept of "cross-cultural code-switching" (i.e., [44], p. 623), which describes it as "the act of purposefully modifying one's behavior, in a specific interaction in a foreign setting, to accommodate different cultural norms for appropriate behavior...for the purpose of creating a desired social impression." It is possible that while both countries are culturally and racially diverse, racial discrimination is particularly at the moment (and at the time of data collection) a very heated topic in the U.S., which could potentially have resulted in a heightened level of "cross-cultural code-switching" in the U.S. participants. In other words, when presented with an Indian local user actor, U.S. participants might have engaged in more behavioral modification to accommodate what they perceived to be the foreign cultural norm.

Another potential explanation for the finding that the U.S. participants kept larger distances between themselves and the U.S. actors than they did with the Indian actors could be due to perceptions of power, dominance, and status. As discussed earlier, among samples of predominantly North American or Northern European individuals, smaller interpersonal distances were found to indicate perceptions of higher power, status, and credibility [2, 28]. Either explanation would need further research to confirm, but we think this interaction effect is an interesting finding that warrants further investigation.

This perplexing interaction effect notwithstanding, our results show that Indian participants' proxemic behaviors differed from those of the U.S. participants. We had used silent videos as stimuli to control for potential audio confounds, and in our analyses, we also controlled for major factors that could affect interpersonal distance behavior (i.e., gender, age, height, self-construal, and past use of telepresence robot). All these give us confidence that the differences we observed between the Indian and the U.S. participants were at least partially due to cultural differences. While the effect sizes found in this



(i) (ii) (iii) (iv)

Figure 7: Visual views of the (raw) mean approach distances. From left to right: mean approach distance of Indian participants toward Indian actors (i), mean approach distance of Indian participants toward U.S. actors (ii), mean approach distance of U.S. participants toward Indian actors (iii), mean approach distance of U.S. participants toward U.S. actors (iv).

study are small, they are in line with those reported in previous research on technology mediated interpersonal distance behavior [72]. To our knowledge, these results are the first to shed light onto robot teleoperators' culturally relevant proxemic behaviors, and provide initial evidence that group level proxemic behaviors can be transmitted through the mediation of the telepresence technology.

Anecdotal data from participant comments about their experience interacting with the teleoperation simulation indicates that our stimulation paradigm was effective in eliciting a sense of robot teleoperation. Participants spoke about a sense of bodily limitation often heard from actual telepresence operators. For example, one participant said: "I couldn't use my own body language as I approached." And another added: "I couldn't express my level of energy or excitement via my gait, or 'spring' in my step." Nevertheless, despite such bodily limitations, our quantitative results show that interpersonal distance behavior tendencies could still be transmitted through teleoperation.

More broadly, these results suggest that at least certain cultural norms about appropriate behavior manifest in the way teleoperators control a robot. Our study provided evidence that nonverbal behavior (in this case interpersonal distance behavior) can be transmitted through an intermediary robot in culture/group-specific ways, just by way of how an operator clicks buttons on a control interface. This suggests that culture/group-specific nonverbal cues could manifest even in teleoperated robots that do not provide audiovisual access to the teleoperator as standard telepresence robots do. For example, a teleoperator could drive a mall security robot too close for comfort for many mall goers without ever realizing it. Thus, the knowledge that one's cultural behaviors can be implicitly transmitted through an intermediary robot is an important consideration for the use of teleoperated robots in intercultural/intergroup settings, particularly for socially sensitive contexts such as patient care, or policing.

Furthermore, the results of this study has important implications for designers of next level robot teleoperation. Automated path planning and navigation is becoming an increasingly prevalent area of research [43, 48, 64, 65] and implementation for telepresence [4, 73] and other mobile robots [39]. We argue that culturally relevant differences in robot teleoperators' proxemic norms should be accounted for in designing the specifications and configurations of these advanced functions, and that in terms of semi-autonomous navigation, a "one distance fits all" approach may not be ideal in cross-cultural HRI implementation. For example, in the case of a robot teleoperator driving a mall security robot too close for comfort for mall goers, the system could be configured with the preferred distance norm of the mall goers to (1) signal warning on the operator's control interface whenever the robot crosses the preset threshold, or (2) trigger semi-autonomous navigation functions that automatically correct path whenever the trajectory of the robot would cross the preset threshold.

Limitations and Future Directions

While our robot teleoperation simulation interface proved to be effective in the present study, features could be improved upon and added to fully tap its potential to be a powerful paradigm for online investigations of robot teleoperator preferences and behaviors. For example, the additions of a "reverse" button and directional buttons would expand its use to more complex navigation paths and teleoperation behaviors.

The present study also had a stimulus sampling limitation. That is, we chose only two actors to represent each culture. As a first step into robot teleoperator cross-cultural research, we wanted to use a simpler study design to first assess whether such culturally relevant group level differences even exist. Now that we have provided initial evidence that they do exist, future work should consider selecting an adequate number of actors to more comprehensively represent the racial diversity of the countries under investigation. Furthermore, employing a manipulation check on participants' perception of actor culture would help to disentangle effects such as the interaction effect found in this study.

CONCLUSION

In an increasingly technological and global world, one may find oneself interacting with a coworker from another country through a company's telepresence robot. What do we need to be aware of in these situations, and how should we design the next level technology to support the social and emotional functioning of those involved? The present study provided initial evidence that a robot teleoperator's culture-specific behaviors can be transmitted to the intermediary robot through the operator's actions on the control interface, at least in terms of interpersonal distance behaviors. We also presented a new robot teleoperation simulation paradigm that can facilitate future online investigations of remote robot operators' perspectives and behaviors. Finally, our results offer an important design insight for the future development of robot teleoperation that takes into consideration culture-specific behaviors of the robot teleoperator.

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation (NSF) under Grant Nos. IIS-1139161 and IIS-1563705. Any findings, recommendations, conclusions, or opinions expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.

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