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The Influence of Height in Robot-Mediated Communication

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***Abstract*—A large body of research in human communication has shown that a person's height plays a key role in how persuasive, attractive, and dominant others judge the person to be. Robotic telepresence systems—systems that combine videoconferencing capabilities with robotic navigation to allow geographically dispersed people to maneuver in remote locations—represent remote users, *operators*, to local users, *locals*, through the use of an alternate physical representation. In this representation, physical characteristics such as height are dictated by the manufacturer of the system. We conducted a two-by-two (relative system height: shorter vs. taller; team role: leader vs. follower), between-participants study (*n* = 40) to investigate how the system's height affects the local's perceptions of the operator and subsequent interactions. Our findings show that, when the system was shorter than the local and the operator was in a leadership role, the local found the operator to be less persuasive. Furthermore, having a leadership role significantly affected the local's feelings of dominance with regard to being in control of the conversation.**

***Index Terms*—Robot-mediated communication; robotic telepresence systems; height; team role; compliance**

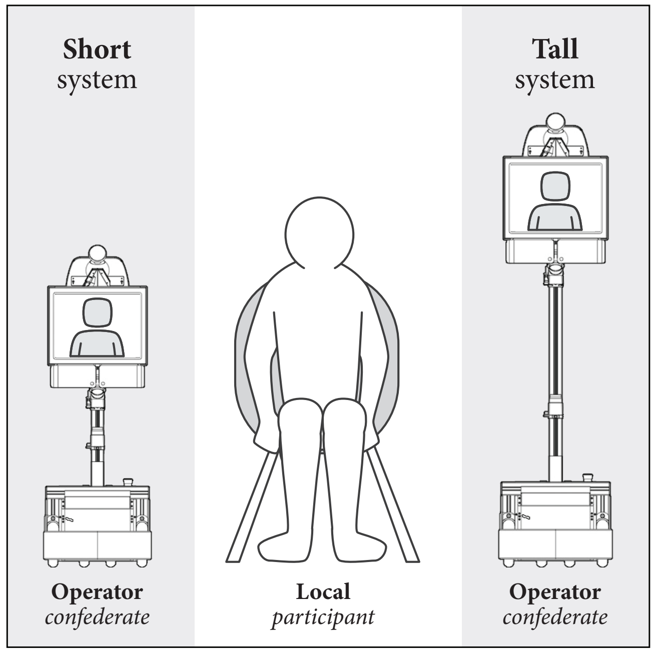

Fig. 1. Example of height differences between a shorter telepresence robot (left), a taller (right) telepresence robot, and a participant.

I. Introduction

From articles about the importance of making a good first impression to dressing up for an important interview, physical appearance has been shown to play a large part in how we are perceived, judged, and treated by others. While there are a multitude of ways in which individuals alter how they present themselves, there are also many characteristics that we have very limited control over, such as our height.

Research in human communication has shown that height can be critical to how people are perceived; being taller is associated with a number of positive traits such as being more poised, self-assured, composed, relaxed, expressive, and persuasive [1], [2]. These traits may also extend to benefits such as higher pay [3] and being judged to be more attractive [4], [5]. While researchers have investigated such benefits in contexts where height is not malleable, how these effects might extend to robotic systems, where designers are able to dictate physical appearance, has yet to be explored.

Telepresence robots are one such system that supports robot-mediated communication and provides designers with the ability to control an alternate physical representation of the remote user. These systems are similar to videoconferencing technology in that they project a video-mediated image of the remote user, the *operator*, onto a screen. However, many of these systems seek to enhance the presence of the operator by extending the capabilities of the system beyond that of video-mediated communication. These enhancements are enabled through robotic technologies that add mobility and greater vision or awareness to the capabilities of the operator [6]. By mounting the videoconferencing screen on a mobile base and allowing the operator to manipulate the cameras, telepresence robots not only enable the remote user to more fully control his or her experience, but also create physical embodiments through which operators can act. By altering aspects of these physical embodiments, designers can shape the relationship between the remote and local users, *locals*, positively or negatively. For example, positive effects might make remote team members feel closer to their local counterparts [7], improving productivity, while negative outcomes may include subverting a remote doctor's authority and causing less treatment compliance in patients [8].

Due to the newly emerging market for telepresence robots and the nascent nature of research in the area, designers and developers lack guidelines for specifying the physical characteristics of these systems. As a result, today's commercially available systems drastically vary in many physical characteristics, such as height. Systems currently on the market stand at static heights of between 40 – 72 inches (101.6 – 182.9 cm) tall [9]–[13] and heights that are adjustable within the range of 30 – 72 inches (76.2 – 182.9 cm) [14], [15].

In this paper, we explore how the *height* of the system, and thus the perceived height of the operator relative to that of the local user, affects robot-mediated communication.

II. Background

In the following section, we discuss related work that provides background for the effects that height has in face-to-face and mediated communication, informing our efforts to untangle the role it plays in communication using robotic products.

A. Height in Human Communication

Research in human communication has shown that differences in height impact how people are perceived [16] and treated [3]. People who are taller relative to the perceiver are associated with being more dominant and thus possessing a host of other positive characteristics, such as being perceived as more relaxed, composed, expressive, dramatic, persuasive, poised, self-assured, having more leadership qualities, and exhibiting less self-censorship [1], [2]. Prior work has observed that taller people are often judged to be more attractive [4], [5] and have received higher pay [3] than their shorter counterparts. These effects are most prevalent in short-term interactions and may diminish in interactions that occur over longer periods [17].

The effects of height on people's perceptions of others and on their subsequent interactions have also been shown to extend into video-mediated communication and virtual reality [18], [19]. Research in these contexts has found that participants communicating via videoconferencing [18] or in virtual reality [19] had increased influence when they perceived themselves to be taller than the person with whom they were interacting.

B. Height in Human-Robot Interaction

Human-robot interaction (HRI) research has explored how people's perceptions of a robot and their interactions with it are affected by its height. For instance, Walters [20] found that participants judged shorter humanlike robots to be less conscientious than taller humanlike robots. In a design study, users preferred the taller robot version of 56 inches (142 cm) to shorter versions because they did not want to bend down to interact with it [21]. While these findings highlight the importance of height in HRI, how they might translate to the domain of robot-mediated communication is an open question.

C. Height in Robot-Mediated Communication

While prototype and research models of telepresence robots such as the Personal Roving Presence [22] have been in existence for over 15 years, advances in robotic technology and wireless networking over the past decade have enabled these systems to become more widely available [9]–[12], [14], [15]. This availability has created many opportunities for designers and for research aimed at creating design guidelines.

Recent studies have explored how telepresence robots are used in naturalistic settings, particularly in organizations [23], [24], in home healthcare [25], and with older adults [26]. Other studies have examined how system appearance and feelings of ownership might affect interactions [7] or have pushed the boundaries of robotic telepresence systems by creating humanlike physical representations of the remote user [27], [28]. While this research has delved into the question of how the visual framing or humanlike qualities of the system affect interactions between the local and the operator, how the relative height of the system might shape interactions between local and remote users has yet to be explored.

D. Roles in Communication

Research in human communication has shown that the roles assigned to individuals in a group may drastically alter behavior in terms of perceived authority, dominance, and aggression [29]. While some work in human-robot interaction has shown that this type of verbal framing can be effective in altering people's perceptions of robotic systems [30], further investigation is needed to understand how this may affect people's perceptions of other humans when their communication is mediated by a robotic telepresence system.

Our study seeks to understand the extent to which the effects of height observed in human communication and human-robot interaction settings generalize to robot-mediated communication. In particular, we look at how height may serve to undermine or support a user's role when a disparity exists between the user's physical and assigned levels of authority. This understanding will provide design guidelines for future development of robotic communication products and promote longer and more natural interactions between geographically distributed people.

III. Hypotheses

Based on this body of prior work, we formulated the central hypothesis that the height of the telepresence robot relative to the height of the local user would support or undermine the local user's feelings of authority when interacting with an operator. In particular, the height of the operator will have the following predicted effects under different authority structures:

Hypothesis 1: When interacting with an operator that is using a shorter telepresence robot, local participants who are assigned a leadership role will exhibit the most dominance.

Hypothesis 2: When interacting with an operator that is using a taller telepresence robot, local participants who are assigned a follower role will exhibit the least dominance.

Hypothesis 3: Local participants interacting with an operator that is using a shorter telepresence robot will exhibit more dominance, regardless of their assigned role, than those who interact with an operator that is using a taller telepresence robot.

IV. Method

To test these hypotheses, we conducted a 2 (relative system height: shorter vs. taller) by 2 (team role: leader vs. follower) between-participants controlled laboratory experiment. All study participants acted as local users and a confederate operated a telepresence robot that was either *shorter* or *taller* than the participant. Participants were also assigned a role as either the *leader* of the team or the *follower* in the team to create differing levels of perceived authority between the users. The confederate operator was a 20-year-old female logged into the telepresence robot from a remote location, approximately 2,000 miles away from the local site. The same confederate operated the robot across all trials.

A. Participants

Forty adults (5 females and 5 males in each condition), whose ages ranged between 18 and 70 years, M = 35.1, SD = 15.7, volunteered to participate. We recruited via a local university's online bulletin board, through e-mail lists, word of mouth from participants of previous studies, and posters placed around the neighborhood. Participants reported that they were somewhat familiar with robots, M = 4.20, SD = 2.27 (1 = not very familiar; 7 = very familiar). They were compensated $20 for each hour of study participation.

B. Tasks

During the study, participants completed two main tasks: the Desert Survival Task and the Ultimatum Task. Both tasks involved negotiation between the local participant and the confederate operator. During each task, we collected video footage from three cameras positioned in the experiment room. The paragraphs below provide more detail on each task.

1) Desert Survival Task: The first task involved a version of the Desert Survival Problem [31] that had been modified to include items which would be recognizable and relevant in a present-day survival situation [7]. We gave participants written instructions describing a bus crash in a desert in New Mexico and asked them to rank a list of nine items in order of each item's importance to their survival. This initial ranking served as the baseline measurement for agreement between the participant and the confederate. The items included a map of New Mexico, a book called *Edible Animals of the Desert*, duct tape, a first-aid kit, a cosmetic mirror, a flashlight (four-battery size), a magnetic compass, one two-quart flask of 100-proof vodka per person, and one plastic raincoat per person.

We chose the Desert Survival Task for several reasons. First, it has been used in previous mediated communication studies (e.g., [7], [18]) and has been tested for both reliability and validity. Second, the task includes a measure of agreement. Third, participants are inclined to believe that they should be good at the task, which results in a large amount of variance.

After the participant's initial ranking, we algorithmically generated a set of initial rankings for the confederate that was consistently different from those of the participant [7]. The confederate and the participant then discussed the differences in their rankings. During the discussion, the participant and the confederate sought to come to a consensus on a final ranking of the items. The confederate followed a pre-scripted dialog, as in previous work [7].

2) Ultimatum Task: Our second task was the Ultimatum Task [32], a negotiation-based economics exercise that has been used in previous work to study perceptions of dominance in a virtual reality setting [19].

The task involves a total of four rounds and a hypothetical pool of $100 to be split between the participant and the confederate in each round. Either the participant proposes a split of the money in the pool and the confederate has the option of accepting or rejecting the split, or vice versa. We also told the participant that if the split was accepted, then the money would be shared accordingly, but if the split was rejected, then neither person would receive any money.

The participant designated the split in the first and third rounds and the confederate proposed the split in the second and fourth rounds. As in previous work [19], the confederate accepted any proposals where she received more than $10 out of the $100. During the second round, the confederate always proposed a 50/50 split, and in the fourth round, the confederate offered a 75/25 split with $75 going to the confederate.

C. Measures

We used measures of agreement from the two tasks, subjective measures via a post-experiment questionnaire, and behavioral data collected through qualitative coding of significant behaviors that indicate the dominance of the participant toward the confederate.

1) Task Measures: In the Desert Survival Task, we measured the compliance of the participant using the difference between the confederate's initial scores and the final consensus rankings. The confederate's initial rankings were calculated to be consistently distant from the participant's; therefore, the difference between the initial rankings of the participant and those of the confederate was consistent across trials. Thus, the difference between the final consensus ranking and the confederate's initial ranking measured how much influence the confederate had on the participant. A larger difference meant that the participant was less persuaded by the confederate's arguments, whereas a smaller difference indicated that the confederate's arguments had more of an impact. In the Ultimatum Task, we used three measures: the initial split proposed by the participant in the first round, the split proposed by the participant in the third round, and whether or not the participant accepted the unfair 75/25 split proposed by the confederate in the last round.

2) Subjective Measures: We used questions from two separate scales that have been tested for reliability and validity in our questionnaire.

Interpersonal Dominance Scale. To measure perceived dominance, we used the Interpersonal Dominance Scale [33], which measures dominance along five dimensions: poise, persuasion, conversational control, panache, and self-assurance. The scale is comprised of 32 statements on perceptions of the other person (e.g., "the other person is more of a follower than a leader;" "the other person had a dramatic way of interacting;" "the other

Fig. 2. A telepresence robot shorter than the local (left) and taller than the local (right).

person did more talking than listening"). Participants expressed their agreement with each statement using a seven-point rating scale (1 = strongly disagree; 7 = strongly agree).

Subjective Value in Negotiation Tasks. We used a modified version of the 16 question Subjective Value in Negotiation Tasks scale which has been tested for validity and reliability [34] to measure the participants' feelings about the tasks. These questions were divided along four dimensions with three to five questions per dimension: feelings about the instrumental outcome of the task, feelings about the self, feelings about the process, and feelings about the relationship.

3) Behavioral Measures: We used research in human communication to identify and to code for behaviors indicative of interpersonal dominance or submission in our video data [33]. These indicators included the percentage of time spent speaking, the ratio of time spent looking at the other person while speaking, and the number of attempts to interrupt the other person. We also coded for indicators of submission such as the amount of time spent listening and the ratio of time spent looking at the other person while listening. In addition, we made qualitative observations on the postures that participants took [35]. Videos were coded by three independent coders and inter-rater reliability was tested using Spearman's rank coefficient with an inter-rater reliability between coders 1 and 2 of $\rho(36) = .92$, $p < .001$ and an inter-rater reliability between coders 2 and 3 of $\rho(18) = .98$, $p < .001$.

4) Other Measures: Following the questionnaires, we administered a manipulation check. To determine whether the manipulations of robot height and assigned role in the team were successful, we asked participants whether they had to look up, down, or straight to interact with the pilot and who the leader of the team was. We also collected demographic information which included gender, participant height, age, occupation, and experience with robots.

D. Manipulations

In the following section, we describe our manipulations of the relative height of the telepresence robot system and of the assigned role of the participant in the team.

1) Height: We used Texai Alpha prototypes, which are telepresence robots equipped with touch screens mounted on mobile robotic platforms as shown in Figure 2. These systems stream video of the operator onto the screen while providing the remote user with the ability to physically navigate through the environment and to control the positioning of the cameras. The *short* telepresence robot measured 41 inches (104.1 cm) to the top of the screen and 46.5 inches (118.1 cm) to the top of the camera. The *tall* system measured 56.5 inches (143.5 cm) to the top of the screen and 61.5 inches (156.2 cm) to the top of the camera. These measurements were adjusted during pre-testing to create a 6 inch (15.2 cm) difference between the eye level of the participant and the perceived height of the operator. At the beginning of each session, participants adjusted the height of their chairs so that their eye levels were at 47 inches (119.4 cm) as depicted in Figure 2.

2) Roles: Participants were randomly assigned a role at the beginning of the study as either the team *leader* or a *follower*. Roles were assigned after the confederate operator and the participant had been introduced. While addressing both the confederate and the participant, the experimenter assigned one of them team leadership and explained that the team leader would be responsible for ensuring that the team reached a consensus in the Desert Survival Task in the time provided and that their final rankings matched.

E. Procedure

Following informed consent, we asked participants to seat themselves and told them that we first needed to calibrate the camera. We placed a checkerboard on the wall next to the seat, and the experimenter asked the participant to adjust his or her chair until the participant's eyes were level with a line measuring 47 inches (119.4 cm) from the ground as shown in Figure 2. The experimenter instructed participants on the Desert Survival Task. Participants reviewed the survival scenario and then took three minutes to record their initial rankings of the survival items. Following the initial rankings, the confederate operator drove into the room, and the experimenter introduced the confederate and the participant to each other as participants. The experimenter then assigned the role of team leader and told the participant and the confederate that they would have 12 minutes to discuss and to reach a consensus on a set of final rankings. After the discussion period was completed, the experimenter re-entered the room, instructed the participant and the confederate on the Ultimatum Task, and exited the room to allow the participant and confederate to complete the exercise. Upon completion of the task, the confederate exited the room and the experimenter administered the post-experiment questionnaire.

F. Analyses

In an exploratory analysis, we sought to determine potential covariates, testing effects of gender, age, and participant height on the dependent variables, and found only height to have a significant effect. We therefore included participant height as a covariate in all final analyses.

1) Task Measures: An analysis of covariance (ANCOVA) was conducted to analyze the measures of agreement from the Desert Survival Task, using the difference between the final consensus ranking and the confederate's initial ranking as the response variable and participant height as a covariate. An ANCOVA was also used to analyze participant's proposed splits in the Ultimatum Task. The first split proposed by the participant in round one and the second split proposed by the participant in round three were the response variables and participant height was a covariate. A Pearson's Chi-squared test was used to determine any effects of height or team role on participants accepting the unfair (75/25) proposal by the confederate. Post-hoc comparisons in all tests used the Bonferroni correction.

2) Subjective Measures: Our analysis of participant responses to the questionnaire included tests of internal consistency along the dimensions defined by the Interpersonal Dominance [33] and the Subjective Value in Negotiation Tasks [34] scales, described earlier in Section IV-C2. Because these measures were adapted from research in human communication, we conducted a confirmatory factor analysis to ensure their reliability in the context of robot-mediated communication. This analysis showed that the items did not reliably compose the sub-scales suggested in the literature. Therefore, we followed up with an exploratory factor analysis to construct new sub-scales from the set of items. Our analysis resulted in two new sub-scales, which we identified as *conversational control* (two items; $Cronbach's\ \alpha$ = .78) and *feelings about the negotiation* (11 items; $Cronbach's\ \alpha$ = .91). The analysis of data from these sub-scales and of the individual questionnaire items involved ANCOVA tests that used participant height as a covariate. Data from the manipulation check questions were analyzed using Pearson's Chi-squared tests.

3) Behavioral Measures: Analysis of the data resulting from our qualitative coding of the videos involved ANCOVA tests, using participant height as a covariate for time-based measures and Pearson's Chi-squared tests for frequency-based behaviors.

V. Results

The analysis of data from manipulation check questions showed that participants were able to distinguish between the different heights of the telepresence robot, χ^2(3, N=36) = $37.0, p < .001$, and assigned roles, χ^2(2, N=38) = $20.8, p <$ .001, across conditions.

Hypothesis 1 posited that when interacting with an operator that was using a shorter telepresence robot, local participants who were assigned leadership would exhibit the most dominance. Our results showed partial support for this hypothesis. We found that locals who interacted with an operator that was using a shorter telepresence robot felt that the negotiation had a more positive impact on their self image M = 5.29, SD = 1.68 than those who interacted with an operator that was using a taller telepresence robot M = 4.50, SD = 1.64, $F(1,34)$ = 4.41, p = .043, $\eta_p{}^2$ = .115 as shown in Figure 3. Locals that interacted with an operator that was using a shorter telepresence robot also showed a tendency toward feeling more satisfied with their relationship with the operator M = 6.05, SD = 1.65, than those who interacted with an operator that was using a taller telepresence robot M = 5.35, SD = 1.65, $F(1,35)$ = 3.54, p = .068, $\eta_p{}^2$ = .092. We also found that locals who interacted with an operator that was using a shorter telepresence robot spent a greater ratio of the total interaction time speaking M = .656, SD = .070 than those that interacted with an operator that was using a taller telepresence robot M = .589, SD = .081, $F(1,33)$ = 8.07, p = .008, $\eta_p{}^2$ = .196. There was a marginal effect of the relative height of the telepresence robot on the total amount of time spent in discussion. Locals who interacted with an operator that was using a shorter telepresence robot spent more time in discussion M = 536.63, SD = 126.82 than those that interacted with an operator that was using a taller telepresence robot M = 479.74, SD = 90.21, F = $(1,33)$ = 2.98, p = .094, $\eta_p{}^2$ = .083.

We found no support for Hypothesis 2, that when interacting with an operator that was using a taller telepresence robot, local participants who were assigned a follower role would exhibit the least dominance. We found that when the local was assigned leadership, locals felt that they were significantly more in control of the conversation, M = 4.33, SD = 1.34 than when the operator was assigned leadership, M = 3.40, SD = 1.31, $F(1,34)$ = 9.81, p = .004, $\eta_p{}^2$ = .224, regardless of the relative height of the telepresence robot. Locals who were assigned leadership felt marginally more relaxed M = 5.78, SE = .289 than those that interacted with an operator who was assigned a leadership M = 4.97, SE = .297, $F(1,34)$ = 3.70, p = .063, $\eta_p{}^2$ = .098. We found no significant effects of the relative height of the telepresence robot or of assigned role on the participant's feelings about the negotiation. We found no main effects for the relative height of the telepresence robot or for assigned role on the measures for agreement in the Desert Survival Task. We also found no significant effects of the relative height of the robot or assigned role in the Ultimatum Task on what the participant chose as a split in their first or second proposals or on whether or not the participant chose to accept the unfair split

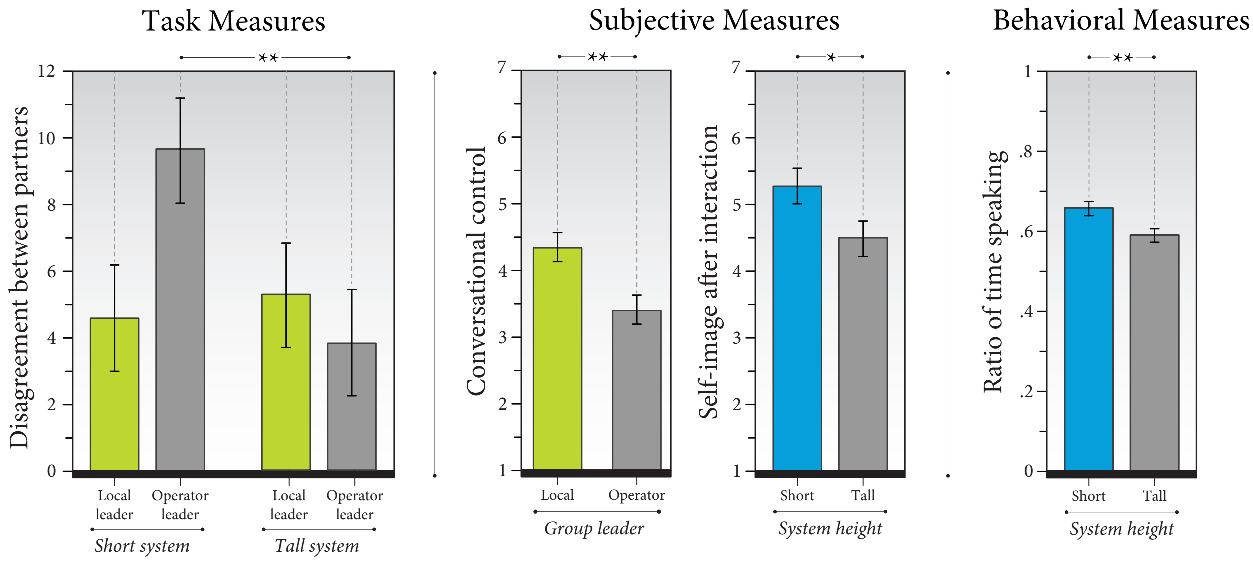

Fig. 3. Results showing significant effects of the relative height of the telepresence robot and assigned role on task (left), subjective (middle), and behavioral (right) outcomes. (*) and (**) denotes $p < .05$ and $p < .01$, respectively.

in the last round of the task. In contrast, we found a marginal effect of assigned role on the ratio of time spent looking at the other person while speaking. When the operator was assigned leadership, locals spent more time looking at the operator when speaking $M = .252$, $SD = .149$ than when the local was assigned leadership $M = .181$, $SD = .096$, $F(1, 33) = 2.98$, $p = .094$, $\eta_p^2 = .083$. There were no significant effects for the relative height of telepresence robot or for assigned role in the amount of time spent listening, the ratio of looking at the other person while listening, or the number of times that locals attempted to interrupt the operator.

Hypothesis 3 predicted that local participants interacting with an operator that was using a shorter telepresence robot would exhibit more dominance, regardless of their assigned role, than those who interacted with an operator that was using a taller telepresence robot. Our results showed support for this hypothesis. We found a significant interaction effect between the relative height of the telepresence robot and assigned role, $F(1, 35) = 4.17$, $p = .049$, $\eta_p^2 = .107$ in the Desert Survival Task. Post-hoc analyses revealed that height only had an effect when the operator was assigned the leadership role, $F(1, 35) = 6.68$, $p = .014$, $\eta_p^2 = .160$; locals were more persuaded by operators who were assigned leadership and who were using a taller telepresence robot, $M = 4.80$, $SD = 3.29$, than locals who interacted with operators who were assigned leadership and who were using a shorter telepresence robot, $M = 9.60$, $SD = 7.65$ (Figure 3). When the local was assigned leadership, the relative height of the robot did not have a significant effect, $F(1, 35) = 0.094$, $p = .762$, $\eta_p^2 = .003$.

In addition, we also found a marginal interaction effect between the relative height of the telepresence robot and assigned role on how well the interaction built a foundation for a future relationship with the operator, $F(1, 35) = 6.86$, $p = .062$, $\eta_p^2 = .096$. Post-hoc analyses (using the Bonferroni correction) revealed that height only had an effect when the participant was leader, $F(1, 35) = 3.73$, $p = .061$, $\eta_p^2 = .096$. Local leaders tended to feel that the interaction built a better foundation for a future relationship when the operator was using a shorter telepresence robot $M = 5.66$, $SD = 3.85$, than when the operator was using a taller telepresence robot $M = 4.84$, $SD = 3.85$. When the operator was leader, height did not have a significant effect, $F(1, 35) = .63$, $p = .433$, $\eta_p^2 = .018$.

VI. Discussion

The results provided limited support for Hypothesis 1; when using a shorter telepresence robot, local participants in leadership roles would exhibit the most dominance. We found no support for Hypothesis 2; when using a taller telepresence robot, local participants in follower roles would show the least dominance. However, when using a shorter telepresence robot, local participants exhibited more dominance, regardless of their assigned role, than those who used a taller telepresence robot, providing support for Hypothesis 3.

We found that locals felt better about themselves and showed more dominance by taking more speaking time (as opposed to listening time) when the operator used a shorter telepresence robot and felt more in control of the conversation when assigned leadership, regardless of the robot's height. However, locals who were assigned a follower role exhibited more dominant behavior in the form of higher ratios of gaze while speaking. Our results also highlight that locals found the operator to be the least persuasive when the operator used a shorter telepresence robot while being in a leadership role. Further analysis may provide insight into why locals had such an adverse reaction to the operator in this condition.

Based on our results, we speculate that when locals were assigned leadership and interacted with an operator who used a shorter telepresence robot, the local's role was reinforced by his or her superior height. Conversely, when assigned a follower role and interacting with an operator who used a taller telepresence robot, the local's role was reinforced by his or her inferior height. However, when interacting with an operator who was assigned leadership while using a shorter telepresence robot, the disparity between the local's assigned role and his or her greater height may have created cognitive dissonance. This dissonance may have triggered more aggressive behaviors in participants, which may explain why locals exhibited more dominance by spending more time speaking than listening to the operator when they were assigned a follower role. Additionally, in our qualitative observations, we noted that locals who interacted with an operator in a leadership role using a shorter telepresence robot spent more time leaning toward the robot in an open and aggressive posture than in any other condition. In taking this type of posture, participants may have triggered short-term physiological changes, making them less agreeable to negotiation [35].

An alternative explanation may be that adults are accustomed to interacting with shorter people, such as children, using an authoritative stance. Communicating via a shorter system, similar in height to that of a child, may have triggered behavior or strategies for interacting with children, who may be aggressive in trying to persuade others.

A. Design Implications

Although our results found that interacting with a taller telepresence robot had no effect in either assigned role, they highlighted the potential negative effects that height might play on an operator's influence when he or she is in a position of power. These effects are of particular importance in contexts where the operator's ability to exert authority are critical to the success of the interaction, such as in businesses 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 prescribing treatment plans for patients. As a result, those designing robotic telepresence systems should be aware of who the potential users of the system are and what their roles may be. For example, if a system is intended for use by remote team members in collaborative tasks, designers may choose to create a shorter system to increase how positive the local users feel about interactions with the operator. However, if systems are expensive and will be reserved for use by company executives in negotiations or by specialists such as doctors, designers may prefer to create taller systems that can aid operators in persuading locals to follow their lead.

B. Limitations

The study presented here has several limitations that may decrease the generalizability of our results. First, the lack of support for our hypotheses in the Ultimatum Task may have stemmed from positioning it after the Desert Survival Task. In previous studies [19], [32], the Ultimatum Task was an independent exercise. Asking the participant to interact with the confederate in a negotiation that requires consensus prior to engaging in the Ultimatum Task might have established a cooperative relationship between the local and the operator, leading to a tendency toward fairness and compromise.

In addition, our inability to match our questionnaire items with the dimensions defined by previous work and the results of our confirmatory factor analysis indicate that these measures may not translate directly from human communication research to robot-mediated communication. More work should be done to further disentangle the subjective effects that the height of the telepresence robot has on the local-operator relationship.

Last, the system that we used for the study forced some physical limitations on how much we were able to adjust for height. For example, during the study, several participants commented on the inability to tilt the screen to an angle appropriate to the system's height. Due to physical stability issues associated with increasing the center of mass, we were unable to increase the height of the robot to investigate differences in the perceptions of the local between seated and standing positions. We were also unable to move the camera on the robot closer to where the confederate appeared on the screen, making it difficult for participants to feel that they were able to maintain eye contact.

C. Future Work

Further studies in this domain may increase the generalizability of our results by examining how the short-term effects of height may evolve over time, how previous contact with the operator may mediate the local's reaction to the height of the system, and how allowing the operator to adjust his or her height may change local user perceptions. Additionally, modifying the angle of the screen may increase the impact that the height of the system has on the relationship between users. Examining the interaction between two non-confederate users in a dyadic study may offer other insights into the repercussions that the height of the system and thus the physical representation of the operator might have in working relationships.

Additional work must also be done to further untangle how other aspects of system appearance might change the dynamics between collaborators. Further work in the proportions of the system, the dimensionality of the operator's representation (e.g., a flat screen, multiple screens oriented in different directions, projected onto a sphere), and the fluidity of the system's movements may reveal additional factors that will influence the design and use of future systems.

VII. Conclusion

Many aspects of physical appearance have been shown to change how an individual is perceived, judged, and treated by others. One of these characteristics shown to have a prominent effect is height. Robotic telepresence systems that extend a remote user's presence through a robotic representation are unique in that designers are able to choose the height and appearance of the system. However, many of the systems that are currently being used have been designed to place remote users at an arbitrary height relative to that of the local users with limited knowledge of how the local-operator relationship might be affected.

In our study, we assigned the role of either a leader or a follower to participants and explored how manipulating the relative height of the telepresence robot to be shorter or taller than the participant reinforced or undermined his or her authority. We found that locals felt that the operator was less persuasive when using a shorter telepresence robot and playing a leadership role. Locals also exhibited more dominance in terms of how much time they spent speaking (vs. listening) and experienced an increase in self-esteem when interacting with an operator using a shorter telepresence robot. In addition, locals in leadership roles felt that they had greater control over the conversation. However, locals in follower roles exhibited greater dominance by looking at the other person more while speaking. While the results presented in this paper are limited to short-term interactions, they provide evidence that the height of robotic telepresence systems may shape interactions between remote and local users. These results not only inform the design of current and future systems, but also reinforce the importance of considering embodiment when designing robotic communication systems and shaping robot-mediated communication.

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References

[1] J. Hall, E. Coats, and L. LeBeau, "Nonverbal behavior and the vertical dimension of social relations: a meta-analysis." *Psychological bulletin*, vol. 131, no. 6, pp. 898–924, 2005.

[2] J. K. Burgoon and N. E. Dunbar, "An interactionist perspective on dominance-submission: Interpersonal dominance as a dynamic, situationally contingent social skill," *Communication Monographs*, vol. 67, no. 1, pp. 96–121, 2000.

[3] T. Judge and D. Cable, "The effect of physical height on workplace success and income: preliminary test of a theoretical model." *Journal of Applied Psychology*, vol. 89, no. 3, pp. 428–441, 2004.

[4] J. Shepperd and A. Strathman, "Attractiveness and height the role of stature in dating preference, frequency of dating, and perceptions of attractiveness," *Personality and Social Psychology Bulletin*, vol. 15, no. 4, pp. 617–627, 1989.

[5] M. Richard and T. Moore, "Sex and status effects on perception of physical attractiveness," *Psychological Reports*, vol. 34, no. 3c, pp. 1047–1050, 1974.

[6] H. Ishiguro and M. Trivedi, "Integrating a perceptual information infrastructure with robotic avatars: a framework for tele-existence," in *Proceedings of the International Conference on Intelligent Robots and Systems*, vol. 2, 1999, pp. 1032–1038.

[7] I. Rae, L. Takayama, and B. Mutlu, "One of the gang: supporting in-group behavior for embodied mediated communication," in *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems*, ser. CHI '12. New York, NY, USA: ACM, 2012, pp. 3091–3100.

[8] R. Gorawara-Bhat, M. A. Cook, and G. A. Sachs, "Nonverbal communication in doctor-elderly patient transactions: Development of a tool," *Patient Education and Counseling*, vol. 66, no. 2, pp. 223–234, 2007.

[9] VGo Communications, Inc., "Vgo," Nashua, NH, 2011 (accessed September 8, 2012), http://www.vgocom.com/.

[10] Suitable Technologies, "Texai," Palo Alto, CA, 2011 (accessed September 8, 2012), http://www.willowgarage.com/pages/texai/overview.

[11] Giraff Technologies AB, "Giraff," Västerås, Sweden, 2010 (accessed September 8, 2012), http://www.giraff.org/om-giraff/.

[12] RoboDynamics, "Luna," Santa Monica, CA, 2011 (accessed September 8, 2012), http://robodynamics.com/.

[13] Gostai R&D, "Gostai jazz," Paris, France, 2013 (accessed January 6, 2013), http://www.gostai.com/connect/.

[14] Anybots, Inc., "Qb," Santa Clara, CA, 2011 (accessed September 8, 2012), https://www.anybots.com.

[15] Double Robotics, "Double," Mountain View, CA, 2012 (accessed September 8, 2012), http://www.doublerobotics.com/.

[16] S. K. Moeller, M. D. Robinson, and D. L. Zabelina, "Personality dominance and preferential use of the vertical dimension of space," *Psychological Science*, vol. 19, no. 4, pp. 355–361, 2008.

[17] D. Lester and D. Sheehan, "Attitudes of supervisors toward short police officers," *Psychological reports*, vol. 47, no. 2, pp. 462–462, 1980.

[18] W. Huang, J. S. Olson, and G. M. Olson, "Camera angle affects dominance in video-mediated communication," in *CHI '02 extended abstracts on Human factors in computing systems*, ser. CHI EA '02. New York, NY, USA: ACM, 2002, pp. 716–717.

[19] N. Yee and J. Bailenson, "The proteus effect: The effect of transformed self-representation on behavior," *Human Communication Research*, vol. 33, no. 3, pp. 271–290, 2007.

[20] M. L. Walters, "The design space for robot appearance and behaviour for social robot companions," Ph.D. dissertation, U. Hertfordshire, 2008.

[21] M. K. Lee, J. Forlizzi, P. E. Rybski, F. Crabbe, W. Chung, J. Finkle, E. Glaser, and S. Kiesler, "The snackbot: documenting the design of a robot for long-term human-robot interaction," in *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction*, ser. HRI '09. New York, NY, USA: ACM, 2009, pp. 7–14.

[22] E. Paulos and J. Canny, "Prop: personal roving presence," in *Proceedings of the SIGCHI conference on Human factors in computing systems*, ser. CHI '98, 1998, pp. 296–303.

[23] K. M. Tsui, M. Desai, H. A. Yanco, and C. Uhlik, "Exploring use cases for telepresence robots," in *Proceedings of the 6th international conference on Human-robot interaction*, ser. HRI '11. New York, NY, USA: ACM, 2011, pp. 11–18.

[24] M. K. Lee and L. Takayama, ""Now, I have a body": uses and social norms for mobile remote presence in the workplace," in *Proceedings of the 2011 annual conference on Human factors in computing systems*, ser. CHI '11. New York, NY, USA: ACM, 2011, pp. 33–42.

[25] F. Michaud, P. Boissy, H. Corriveau, A. Grant, M. Lauria, D. Labonte, R. Cloutier, M. Roux, M. Royer, and D. Iannuzzi, "Telepresence robot for home care assistance," in *Proceedings of AAAI Spring Symposium*, 2007, pp. 50–56.

[26] J. M. Beer and L. Takayama, "Mobile remote presence systems for older adults: acceptance, benefits, and concerns," in *Proceedings of the 6th international conference on Human-robot interaction*, ser. HRI '11. New York, NY, USA: ACM, 2011, pp. 19–26.

[27] D. Sakamoto, T. Kanda, T. Ono, H. Ishiguro, and N. Hagita, "Android as a telecommunication medium with a human-like presence," in *Proceedings of the ACM/IEEE international conference on Human-robot interaction*, ser. HRI '07. New York, NY, USA: ACM, 2007, pp. 193–200.

[28] K. Ogawa, S. Nishio, K. Koda, K. Taura, T. Minato, C. T. Ishii, and H. Ishiguro, "Telenoid: tele-presence android for communication," in *ACM SIGGRAPH 2011 Emerging Technologies*, 2011, p. 15.

[29] P. Zimbardo and A. Cross, *Stanford prison experiment*. Stanford U., 1971.

[30] F. Yamaoka, T. Kanda, H. Ishiguro, and N. Hagita, "Interacting with a human or a humanoid robot?" in *Proceeding of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2007)*, November 2007, pp. 2685–2691.

[31] J. Lafferty, P. Eady, and J. Elmers, "The desert survival problem," *Experimental Learning Methods*, 1974.

[32] R. Forsythe, J. L. Horowitz, N. Savin, and M. Sefton, "Fairness in simple bargaining experiments," *Games and Economic Behavior*, vol. 6, no. 3, pp. 347–369, 1994.

[33] J. K. Burgoon, M. L. Johnson, and P. T. Koch, "The nature and measurement of interpersonal dominance," *Communication Monographs*, vol. 65, no. 4, pp. 308–335, 1998.

[34] J. Curhan, H. Elfenbein, and H. Xu, "What do people value when they negotiate? mapping the domain of subjective value in negotiation." *Journal of Personality and Social Psychology*, vol. 91, no. 3, pp. 493–512, 2006.

[35] D. Carney, A. Cuddy, and A. Yap, "Power posing," *Psychological Science*, vol. 21, no. 10, pp. 1363–1368, 2010.