Closeness is Key over Long Distances: Effects of Interpersonal Closeness on Telepresence Experience

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ABSTRACT

Telepresence robots act as the remote embodiments of human operators, enabling people to stay connected to friends, family, and coworkers over lengthy physical separations. However, the factors affecting how humans can best make use of such systems are not yet well understood. This paper explores the effects of personalization and relationship closeness on telepresence via two studies. Study 1 was a between-participants experiment that investigated telepresence robot personalization. 32 pairs of friends (N = 64) participated in the study's team-building-style activities and answered questions about robot operator presence. The results unexpectedly indicated that relationship closeness influenced the interaction experience more than any other considered predictor variable. To study closeness more rigorously as the central manipulation, we conducted Study 2, a between-participants experiment with 24 pairs (N = 48) and a similar procedure. Robot operators who reported a closer relationship with their teammate felt more present in this investigation. These findings can inform the design and application of telepresence robot systems to increase a remote operator's feelings of presence via robot.

KEYWORDS

telepresence robots, personalization, relationship closeness, remote presence

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Figure 1: Telepresence personalization study setup in which a robot operator and friend completed activities together.

1 INTRODUCTION

In today's world, students increasingly pursue remote classes for secondary education, remote work in industry is becoming more common each year, and families are regularly separated by large geographic distances. Robotic telepresence offers a way to keep people in all of the above scenarios better connected, but many aspects of telepresence are not yet well understood. While robot personalization has been used in past work [9, 10, 16, 18, 23], we believe that the experiments presented in this paper are the first to systematically examine the effects of diverse robot personalization and interpersonal closeness upon telepresence robot experience and usage. In our pair of studies, we investigated how **telepresence robot personalization** and **interpersonal closeness** affect **feelings of presence** and **behaviors** of robot operators and their friends who are physically co-present with the telepresence robot (hereafter referred to as *co-present* participants).

Past studies of mobile phones have shown that phone customization can lead to stronger connections with these devices and increased feelings of representation [3, 6]. Similar trends have been found in past robotics research [26, 27]. In telepresence scenarios, personalization of the robot can potentially influence the experience of both the remote robot operator and people co-present with the robot. Although it can be challenging for telepresence users to feel integrated and present in remote environments, robot personalizations that represent the operator could increase feelings of operator presence. Personalization can also help co-present people to identify the robot operator with the robot itself and feel more connected to the operator's robot embodiment. At the same time, isolating the effects of telepresence personalization can be challenging, especially as other factors (e.g., relationship between the operator and co-present people) can greatly influence the interaction. In [10], telepresence robot customization did not show any effects on short-term interactions between a robot operator and stranger during an educational activity.

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In the current work, we employ a wider range of personalization methods, such as items motivated by past research [9, 16, 18], decals [10, 27], and the robot operator's own personal belongings, to explore the effects of personalization on a robot operator's feelings of presence. Related work is described in more detail in Section 2. Sections 3 and 4 cover the methods and results of the first study (Study 1), which focused on personalization effects on the team navigation and puzzle-solving tasks shown in Fig. 1. After finding relationship closeness to be particularly important in the first study, we examined closeness as the main manipulation in the follow-up investigation presented in Sections 5 and 6. This study (Study 2) centered on relationship closeness effects during a telepresence-mediated team interaction. The discussion in Section 7 highlights how our findings can inform effective use of telepresence robots.

2 RELATED WORK

This section reviews related research that grounds our exploration of the effects of telepresence robot personalization and interpersonal closeness on feelings of presence via telepresence robot.

Telepresence Robot Technologies: A telepresence robot is a system that is capable of navigating a remote environment while performing two-way video and audio conferencing [12]. One of the earliest telepresence robots was the Personal Roving Presence (PRoP) robot [21]. Several subsequent efforts have focused on using telepresence systems to minimize the separation of remote employees from the workplace; past work has demonstrated that the physical distance between remote employees and their workplaces leads to significant challenges and setbacks to productivity [19]. Even with the advent of the digital age, key challenges, such as differences in time zones and lack of impromptu meeting ability, remain [20].

Therefore, telepresence research has frequently explored the effects of using robots to physically embody remote workers. Past studies found that telepresence robot usage over 2- to 18-month periods helped remote workers to feel present in the workplace [13] and that physically embodied telepresence systems led to more attention and affinity toward remote workers [30]. Other early efforts revealed remote worker requirements (e.g., dynamic volume control, an articulated neck) for telepresence robots [29].

Further works have considered telepresence robot usage in additional applications, including education [1, 9, 11, 18] and academic conferences [17]. Our work generally aims to better understand how to keep physically separate people connected with the help of telepresence robots. We start by exploring the connections and teamwork interactions of adult telepresence robot users.

Robot Personalization: Past research on remote work and telepresence has consistently involved aspects of personalization. In [19], knowing the identities of the remote technology system users was found to be important. Early work considered how decorations of computers and mobile phones would affect the way people connected with those devices [3]. Past efforts on studying workplace telepresence [13] and representing individual users at academic conferences [16, 17, 22] have used hats, scarves, wigs, and other decorations to help clarify the identity of the telepresence user. In education efforts, telepresence technologies were likewise adorned with t-shirts, tutus, decals, and other aesthetic customizations [9, 10, 18]. Personal robot decoration has also extended to household robots like the Roomba vacuum cleaner; one study demonstrated that Roomba personalization improved user perception [27].

When working with student populations in particular, the personalization of robots may extend beyond functional purposes; children and youths express themselves in many ways on a daily basis through decisions from what to wear to how to decorate their belongings. These tendencies extend to technology as well; in educational robotics efforts, researchers have allowed children to decorate and personalize robots to help them feel more connected to the technology [26]. Children and adults alike tend to personalize mobile phones and other everyday technologies to represent an extension of themselves [4, 6]. By understanding the effects of telepresence robot personalization on a general population of adults, we can begin to understand how to better support telepresence users.

Relationship Closeness in Remote Communication: Our interest in the effects of interpersonal closeness on telepresence experience arose from the results of the initial study presented in this paper, but past work in remote communication and beyond has also considered relationship closeness. For example, one past study on a "fast friending" procedure in distance learning showed that students felt more socially integrated after this treatment [25]. In a similar way, virtual communities who have a close relationship with other group members are more emotionally attached to the group than communities without these relationships [14]. Friendship closeness has been found to be positively correlated to social network use and online gaming for individuals from collectivist cultures [15]. Overall, some past work has considered relationships between closeness and remote communication experiences, but closeness is more commonly studied as an outcome than a manipulation, and limited past telepresence research has centered on relationship closeness.

3 PERSONALIZATION STUDY METHODS

To first assess the effects of robot personalization, we conducted an initial between-subjects study (Study 1) in which pairs of friends worked together to complete team-building-style challenges. From each pair, one participant was the operator, using the telepresence robot to join in the challenges, while the other participant was co-present with the robot. All study procedures were approved by the University of Southern California Institutional Review Board under protocol #UP-17-00639.

3.1 Hypotheses

Based on the results of past telepresence robot research, we developed the following hypotheses about how personalization might affect the feelings of presence and behaviors of involved parties:

- **H1**: The robot operator will feel more present when the robot is personalized.
- **H2**: The co-present person will perceive the robot operator as more present when the robot is personalized.
- **H3**: The co-present person will help the robot more when it is personalized.

3.2 Study Design

The two study conditions were as follows:

Figure 2: Setup and example personalization items used in the study. Left: The stationary stand and robot. Center: Personalized stand in the control condition. Right: Personalized robot in the experiment condition.

- **Personalized robot** *(experiment condition)*: We asked the participants to personalize the telepresence robot to represent the robot operator. We asked the robot operator to lead the process and the co-present friend to assist and advise along the way. The personalized robot was subsequently used during the study activities.
- **Non-personalized robot** *(control condition)*: Participants carried out the same personalization steps and received the same prompts as above, but instead of personalizing the robot, participants personalized a physically analogous, stationary stand. The non-personalized robot was subsequently used during the study activities; the stand was not used in the activities, but remained in the study space. Thus, this condition involved the same (often playful and social) opening interaction while allowing for the desired manipulation.

For both conditions, the two participants were physically co-located with the robot/stand during the personalization process. Placement of the robot and stand appear in Fig. 2, along with personalized examples of each.

In both conditions, we offered these personalization options to participants based on past personalization literature [4, 8, 16, 27]:

- *Clothing items*: we provided the following representative selection of men's and women's seasonal clothing: shirts, dresses, shorts, skirts, scarves, bandanas, and hats.
- *Wigs and stick-on facial hair*: we provided a fairly diverse set of hair colors, lengths, and styles and mustache and eyebrow shapes and colors.
- *Stickers*: participants could print up to three stickers from redbubble.com and affix them to the robot or stand as desired.
- *Name tags*: participants could also add a name tag with handwritten content to the robot or stand.
- *Free choice items*: we requested (but did not mandate) that participants bring up to three items to their study session that represented them, asking that the total weight of all items be less than one pound.

In both conditions, the telepresence robot, stand, and personalization items were all in close proximity within a 10' × 10' area.

3.3 System

We used the OhmniLabs Ohmni telepresence robot in this study. This platform allows for two-way video and audio conferencing and navigating around distant spaces, in addition to head screen tilting movement. Figure 1 shows the robot in the study environment.

3.4 Participants

We recruited 32 pairs of friends for the study; all pairs successfully completed the procedure. These 64 adults (27 male, 37 female) were aged 18 to 24 years old (M = 20.2, SD = 1.8). One participant was randomly chosen from each pair to be the robot operator. Most participants were university students. Half identified as having a technical background, and all but two reported no past experience with telepresence robots. One person with telepresence experience had the role of robot operator, and no two participants with telepresence experience were paired together. Each individual participant received US$35 for participating in the 90-minute study.

We asked participants about the frequency of their use of common technologies related to telepresence. These questionnaire items were rated on a scale of 1=never, 2=yearly, 3=monthly, 4=weekly, 5=daily, 6=hourly, 7=all the time. On average, participants reported that they rarely used robots (M=1.7, SD=0.8), never used telepresence robots (M=1.1, SD=0.4), used videoconferencing weekly (M=3.8, SD=0.9), and played video games monthly (M=3.2, SD=1.2).

3.5 Team-Building-Style Activities

Study participants completed two different team-building-style activities. The tasks were designed to resemble situations common to interactions between a remote robot operator and individuals co-present with the physical robot.

Navigation Activity: This task relates to the real-world scenario of a telepresence robot being physically stuck or experiencing network latency. For individuals co-present with the robot, there might be an incentive to help the robot if they know the operator, but this assistance may come at a cost, such as arriving late to a meeting/class or being separated from other colleagues/friends.

Before this activity, participants read instructions on the navigation activity steps described below. The research assistant told the pair that the best overall lap completion time so far was 100 seconds, and that their performance evaluation would be based on the time taken to complete each navigation lap. The activity involved the following steps:

- *Lap 1*: The robot operator (with full telepresence robot functionality) navigated a snaking path with chair obstacles, aided by verbal feedback from the co-present teammate. We designed parts of the path to be challenging for the robot (e.g., including tight turns, protruding furniture legs, and bumpy surfaces that are difficult for the robot to traverse).
- *Lap 2*: The robot operator navigated the same path with obscured vision. The downward-facing camera was fully covered, and the forward-facing camera was blocked except for a small strip near the top. The co-present teammate could provide verbal help (with no penalty) or physical assistance (with a two-second penalty per touch).

Puzzle Activity: This task relates to situations when a remote robot operator and co-present partner may need to solve problems together. For example, remote students might use telepresence robots to collaborate with lab partners in science labs or remote workers might discuss the design of a product with colleagues.

Participants read instructions for the puzzle activity and were told that they had fourteen minutes to complete this activity and that their performance evaluation would be based on how many puzzles they completed. The pair then began the following puzzles:

- *Puzzle 1*: This puzzle involved the assembly of a building block structure that led to the ordering of international flag symbols into the words of a common expression: "There's no place like". Participants could decode the symbols and complete the sentence with "home" to solve the puzzle.
- *Puzzle 2*: In this task, the participants needed to determine a lock combination by summing together playing card values. Opening a locked briefcase led to the puzzle answer: the word "wow" printed on a sheet of paper.
- *Puzzle 3*: This activity presented participants with a square grid of zeros and ones. Coloring in all the ones revealed a QR code that could be scanned by a phone (included in the puzzle supplies) to reveal the solution: the word "bandit".

3.6 Procedure

We recruited pairs of friends to enroll in our study using a university posting board. The study procedures took place in a conference room space arranged as pictured in Fig. 1. Study condition and activity order were assigned in a randomized, counterbalanced order before each session. Two researchers conducted the study together. At the start of each session, a research team member explained that the study would involve team-building-style challenges that one teammate would contribute to via a telepresence robot. Each participant then completed a consent form and demographic survey.

Next, the pair had up to ten minutes to personalize the robot (or analogous stand, in the control condition) to make it represent the robot operator. A research assistant helped to affix items as needed and checked that the view of the downward-facing robot camera was not obscured by the personalizations.

The robot operator next moved to a physically separate workstation and received a brief robot operation tutorial from one research assistant, who then sat at a desk near the robot operator for the remainder of the session. The other research assistant remained in the conference room, next instructing the participant pair to work together to help the robot operator move around the room and look into three mirrors around the space as a brief robot training exercise. This researcher then left the participants alone to learn and explore for four minutes. After this free exploration period, the research assistant returned and the participant pair completed the two team-building-style activities described in Section 3.5. A survey followed each activity, and participants completed a final survey and interview at the end of the session.

3.7 Measurement

An assessment at the start of the study captured participant demographics, personality types, experience with technology, perceptions of technology, and closeness to the partner. Of past closeness inventories in [2] and and [5], we selected the former for our evaluation of closeness because of its suitability for measuring closeness that was not necessarily romantic or social support-related. Based upon that prior work, we calculated a single *relationship closeness* score that was the summed total of the following items from [2]:

(1) My teammate does not influence everyday things in my life. (reversed scale)
(2) My teammate influences important things in my life.
(3) My teammate influences which parties and other social events I attend.
(4) My teammate does not influence my moods. (reversed)
(5) My teammate does not have the capacity to influence how I act in various situations. (reversed)
(6) My teammate influences how I spend my free time.
(7) My teammate influences when I see them and the amount of time the two of us spend together.
(8) My teammate does not influence how I dress. (reversed)
(9) My teammate influences how I decorate my home (e.g., dorm room, apartment, house).
(10) My teammate influences what I watch on TV.

These items were rated on a 7-point Likert scale ('Strongly Disagree' to 'Strongly Agree'), so the score range for this factor was 10 to 70.

Surveys after each activity and after the study overall recorded participant perceptions of robot operator presence. These surveys (based on past work on self-ownership [28] and self-presence in virtual environments [24]) were completed separately by the robot operator and co-present friend. The list of *presence questions* phrased for the robot operator appear below:

(1) Using the robot is a good way for me to express myself.
(2) The robot is an extension of me.
(3) It seemed like I was in control of the telepresence robot.
(4) It seemed like I could go anywhere in the remote space.
(5) It seemed like the robot began to resemble me.
(6) When I looked in the mirror, it seemed like I was looking directly at myself, rather than at an object.
(7) When using the telepresence robot, do you feel physically close to the objects and other people in the remote environment?
(8) When something happens to the telepresence robot body, to what extent does it feel like it is happening to any part of your body?
(9) When using the telepresence robot, to what extent do you feel like you can reach into the remote space through the robot?

A complementary version of questions 1-8 above was presented to co-present participants to capture their perception of robot operator presence. For brevity, we later refer to these questions by number. Bimodal items were rated on a 7-point scale ('Strongly Disagree' to 'Strongly Agree'), and unimodal items were rated on a 5-point scale ('Not at All' to 'A Great Deal').

The research team also conducted closing semi-structured interviews with the robot operator, the co-present participant, and both parties together. To facilitate later transcriptions of study dialog, video and audio recordings of the study activities were captured using an overhead security camera in the conference room space, screen capture on the robot operator computer, and voice recorders.

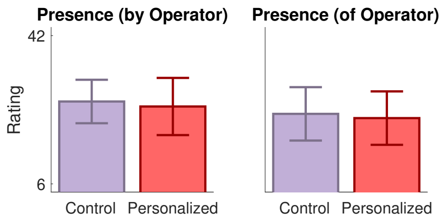

Figure 3: Combined presence ratings for robot operators (left) and co-present participants (right) over condition. The bars show the mean response for each grouping, and the error bars illustrate +/- one standard deviation.

3.8 Analyses

We collected the listed measurements to evaluate self-reported ratings of presence, feelings of ownership by the robot operator, feelings of empathy by the co-present person, and team performance. We compared survey responses to identify differences in presence experiences across condition. To evaluate co-present person empathy, we looked for differences in the number of physical assists in the navigation activity. We analyzed team performance by looking for differences in completion times and words spoken by each participant in each activity. Our tools for identifying differences included t-tests, correlations, and analysis of covariance tests (ANCOVAs) with an $\alpha = 0.05$ significance level.

4 PERSONALIZATION STUDY RESULTS

Our analysis approach allowed us to test hypotheses **H1**, **H2**, and **H3**. *Relationship closeness* was an important pair-level variable that we decided to control for. The relationship closeness scores in this sample (averaged across each participant pair) ranged from 24.5 to 63.5 ($M = 42.4$, $SD = 10.5$).

Participants who had closer relationships spent more time personalizing the robots (Pearson's $r = 0.44$, $p = 0.006$). They also used more items to decorate the robots (Pearson's $r = 0.46$, $p = 0.008$). People with closer relationships also did the obstacle course slower in both lap 1 (Pearson's $r = 0.31$, $p = 0.003$) and lap 2 (Pearson's $r = 0.36$, $p = 0.044$). Because of these notable correlations, we chose to use relationship closeness as a covariate in the subsequent analyses.

4.1 Presence Results

To test **H1** and **H2**, we analyzed the gathered survey data to evaluate if a robot operator feels/seems more present when the robot is personalized. This information was successfully gathered for all participants except one operator. These hypotheses were not supported by the questionnaire results of this study.

We ran factor analyses on the overall presence items for co-present participants and robot operators. For the *robot operators*, we found that six presence questionnaire items formed a single reliable factor (Cronbach's $\alpha = 0.78$): survey questions 1, 2, 4, 5, 6, and 7. For the *co-present participants*, we found that six questionnaire items formed a single reliable factor (Cronbach's $\alpha = 0.84$): questions 1, 4, 5, 6, 7, and 8 from the previously mentioned co-present participant variant of the presence survey. For each factor, we computed a factor score for operators and non-operators separately. These factors, plotted across condition, appear in Fig. 3.

An ANCOVA (between-subjects factor: robot personalization; covariate: relationship closeness; dependent variable: operator's overall sense of presence) revealed no main effect of personalization ($F(1, 28) = 0.50$, $p = 0.48$) or relationship closeness ($F(1, 28) = 1.22$, $p = 0.28$). We did not find support for the hypothesis that *robot operators* would feel more present when the robot was personalized.

An additional ANCOVA (between-subjects factor: robot personalization; covariate: relationship closeness; dependent variable: non-operator's overall sense of presence) revealed no main effect of robot personalization ($F(1,29) < 0.01$, $p = 0.98$) or relationship closeness ($F(1,29) = 1.35$, $p = 0.26$). We did not find support for the hypothesis that *co-present participants* would find the robot operator to be more present when the robot was personalized.

4.2 Assistance Results

We analyzed the number of physical assists from the co-present friend to evaluate **H3**. No differences emerged from the statistical analyses of the *physical assistance* counts during the second step of the navigation task. An ANCOVA (between-subjects factor: robot personalization; covariate: relationship closeness; dependent variable: times robot was physically assisted by non-operator) revealed no main effect of robot personalization ($F(1,29) = 0.18$, $p = 0.68$) or relationship closeness ($F(1,29) = 1.98$, $p = 0.17$).

During post-activity interviews, several co-present friends mentioned that they had faith in the robot operator's motion abilities, wanted to let them try to move on their own, or felt that the strategy of touching the robot would be non-optimal. Two of the 32 co-present friends forgot about the option to physically assist the robot. Although one robot operator during study piloting felt strongly affected and bothered when their co-present friend moved the robot, no other participants shared this same feeling. All of these elements contributed to the complexity of this measure.

4.3 Relationship Closeness Results

Because relationship closeness was consistently correlated with how much effort people put into personalizing the telepresence robot, we examined its effects more closely. If a pair rated their relationship closeness as being low (i.e., below the median split, scores ≤ 43), then they spent an average of 253 seconds personalizing the robot (SD=125). If the pair rated their relationship closeness as being high (i.e., above the median split, scores > 43), then they spent an average of 378 seconds personalizing the robot (SD=152). Running an independent samples t-test revealed that this was a statistically significant difference ($t = -2.53$, $df = 30$, $p = 0.01$). That is, people spent nearly 1.5 times as much time personalizing the robot if they were closer friends as opposed to less close friends.

Similarly, less close friends used an average of 4.5 items to decorate the robot ($SD = 1.0$), whereas closer friends used an average of 5.7 items to decorate the robot ($SD = 1.5$). Running an independent samples t-test revealed that this was a statistically significant difference ($t = -2.62$, $df = 30$, $p = 0.01$). People used more than one additional item to personalize the robot if they were closer friends, as opposed to less close friends.

We also performed exploratory analyses to understand the impact of closeness on other important dependent variables in our dataset, especially with regard to participants' overall sense of presence via the telepresence robot. We found that relationship closeness and frequency of videogaming were significant predictors of how present the *robot operators* felt via these robots. An ANCOVA (between-subjects factor: relationship closeness; covariate: frequency of videogaming; dependent variable: robot operator's overall sense of presence) revealed a statistically significant main effect of relationship closeness ($F(1,28) = 4.39$, $p = 0.045$) and a statistically significant main effect of videogaming frequency ($F(1,28) = 4.46$, $p = 0.044$). Operators who were closer friends with their partner felt a stronger sense of presence via the robot than operators who were less close with their partner.

On the other hand, we did not find significant effects for the *non-operator partners*. An ANCOVA (between-subjects factor: relationship closeness; covariate: frequency of videogaming; dependent variable: non-operator's overall sense of presence) did not reveal a main effect of relationship closeness ($F(1,29) = 0.33$, $p = 0.57$) or of videogaming frequency ($F(1,29) = 2.63$, $p = 0.12$).

5 CLOSENESS STUDY METHODS

To more carefully study the effects of relationship closeness on the telepresence experience, we conducted a between-subjects study (Study 2) with participant pairs working together via telepresence. Again, one participant from each pair was the operator, using the telepresence robot to join in the challenge, while the other participant was physically co-present with the robot. All study procedures were approved by the Oregon State University Institutional Review Board under protocol #IRB-2019-0173.

5.1 Hypotheses

Based on the findings of our initial study and the results of past research on relationship closeness, we developed the following hypotheses about how relationship closeness might affect the feelings of presence and behaviors of involved parties:

- **H4**: A robot operator will feel more present if they have a pre-existing close relationship with their teammate.
- **H5**: Presence perceptions of a co-present person will not be significantly affected by pre-existing relationship closeness.
- **H6**: Participant pairs will work more effectively together if they have a pre-existing close relationship.

5.2 Study Design

Because of the importance of interpersonal closeness in our initial study, we focused on recruiting from two groups in this follow-up study: **acquaintances** and **close friends**. We measured the relationship between the two individuals in each pair using the same relationship closeness inventory as in Study 1 [2]. In this past relationship inventory work, the authors identified the mean values for acquaintanceships and close relationships; we define the midpoint between them as the follow-up study's closeness threshold and use it to conduct a split of the dataset.

5.3 System

To investigate how well the closeness results from the initial study generalize to other common telepresence systems, we used the Suitable Beam Plus telepresence robot in this study. Like the Ohmni robot, this platform allows for remote environment navigation and

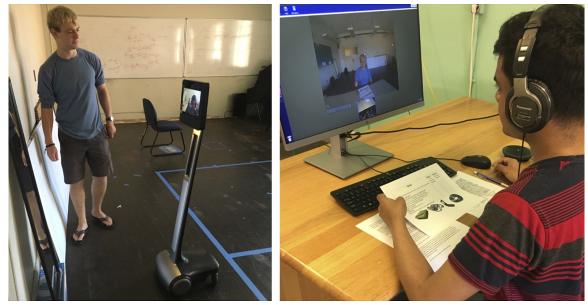

Figure 4: Example relationship closeness study setup. Left: A physically co-present friend interacts with the Beam robot in a user study room space. Right: A robot operator sits at a desk in a physically separate space.

two-way video and audio conferencing. Figure 4 shows the robot in the study environment.

5.4 Participants

We recruited 24 pairs of people with a variety of relationships for the study; all pairs successfully completed the procedure. There were no repeat participants from Study 1. These 48 adults (27 male, 21 female) were aged 18 to 81 years old (M = 24.7, SD = 10.7). One participant was randomly chosen from each pair to be the robot operator. Most participants were university students. Six participants identified as having a non-technical background, and all but four reported no past experience with telepresence robots. One person with telepresence experience had the role of robot operator, and no two participants with telepresence experience were paired together. Each individual participant received US$15 after the 60-minute study.

We again asked participants about their use of telepresence-related technologies, using the same scales. In this sample, participants reported that they used robots monthly (M=3.2, SD=1.8), almost never used telepresence robots (M=1.1, SD=0.4), used video-conferencing every few days (M=4.6, SD=1.1), and played video games biweekly (M=3.6, SD=1.3).

5.5 Procedure

This follow-up study was completed with a similar procedure to Study 1. For this follow-up study, we aimed to recruit pairs with a wider range of relationships (e.g., friends of friends, acquaintances, old friends, couples). To emphasize the team dialog and interaction more than other parts of the activity experience, we used the Subarctic Survival Problem [7] with a truncated ten-item list as the team-building exercise in this follow-up work. In this activity, each teammate completed individual rankings of ten items for their usefulness to survival in a given scenario, and then the pair discussed their thoughts and established a team ranking.

5.6 Measurement and Analyses

The measurement was the same as for Study 1, apart from the following small changes. Because the activity was more discussion-centric than motion-based, we omitted questions 4 and 8 from the previous presence questionnaire. We administered the presence

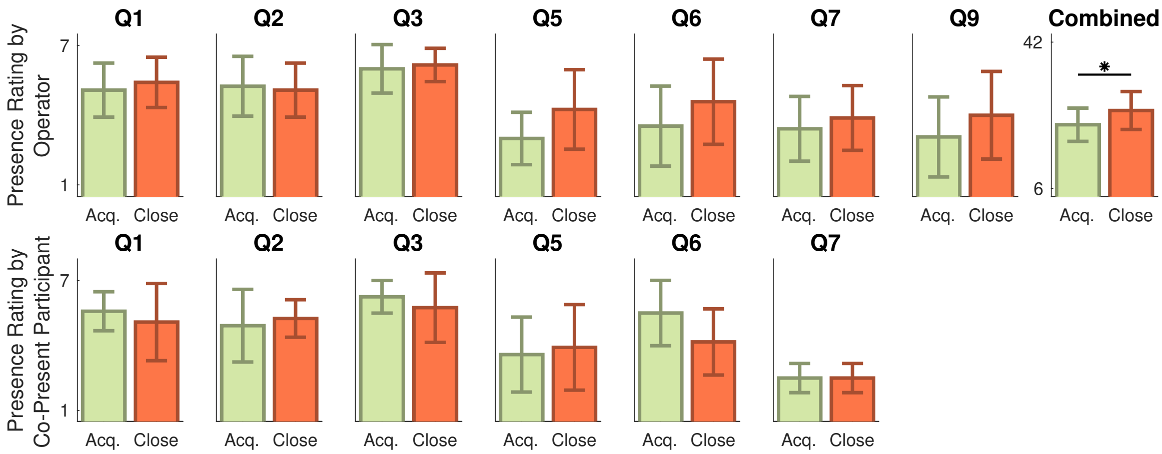

Figure 5: Presence ratings for robot operators (top row) and co-present participants (bottom row) over closeness condition (acquaintanceship or close relationship). The bars show the mean response for each grouping, and the error bars illustrate +/- one standard deviation. Stars indicate significant differences.

questions only once, after the survival activity. In addition to survey data, we recorded time to complete the team rankings, amount of change from individual to team rankings, and accuracy of team rankings compared to an expert's ground truth list. Analyses were similar to Study 1; our main tool was ANCOVAs with a between-subjects factor of relationship closeness, and we considered the survey and behavioral measurements above.

6 CLOSENESS STUDY RESULTS

Analyses on the follow-up study data allowed us to test hypotheses **H4**, **H5**, and **H6**. By recruiting individuals with different types of relationships, we attained a relatively balanced set of 22 participants who reported a *close relationship* with their teammate and 26 who found their teammate more of an *acquaintance* (as determined by the relationship closeness inventory). The threshold between these two categories was set at 29.7: the value of the midpoint between close relationships and acquaintanceships from [2], scaled based on the number of closeness questions we used. Because of its relevance in Study 1, we again included videogaming frequency as a covariate.

6.1 Presence Results

To test **H4** and **H5**, we analyzed survey data to discern if a robot operator feels/seems more present when they have a close relationship with their teammate. These hypotheses were largely supported by questionnaire data.

We ran factor analyses on the overall presence items for co-present participants and robot operators. For the robot operators, we found that six questionnaire items formed a single reliable factor (Cronbach's $\alpha = 0.72$): questions 1, 3, 5, 6, 7, and 9 from the presence survey mentioned previously. We were unable to identify a reliable combined factor from any combination of co-present participant responses, so we considered each survey question individually for these participants and used a Bonferroni correction to adjust for multiple comparisons (p-value cutoff = 0.05 / 6 = 0.0083). Relevant ratings and differences appear in Fig. 5.

An ANCOVA (between-subjects factor: relationship closeness; covariate: frequency of videogaming; dependent variable: robot operator's overall sense of presence) revealed a statistically significant effect of relationship closeness ($F(1,21) = 5.47$, $p = 0.029$) and no effect of videogaming experience ($F(1,21) = 2.33$, $p = 0.142$). We found support for the hypothesis that *robot operators* feel more present when they have a closer relationship with their teammate.

A set of ANCOVAs (between-subjects factor: relationship closeness; covariate: frequency of videogaming; dependent variable: each survey question response) revealed one trend toward a main effect of relationship closeness on how much the co-present participant felt they were directly seeing their teammate when looking at the robot ($F(1,21) = 4.52$, $p = 0.045$) and one trend toward an effect of videogaming experience on how much the robot seemed to resemble the operator ($F(1,21) = 5.67$, $p = 0.027$). *Co-present participants* actually trended toward feeling less like they were looking at their teammate if they had a closer relationship, and more frequent videogamers tended to feel more like the robot resembled their teammate. No other near-to-main effects appeared due to relationship closeness (all $F < 1.00$, all $p > 0.327$) or videogaming frequency (all $F < 2.42$, all $p > 0.134$).

6.2 Performance Results

To assess the differences in team performance based on relationship closeness expected by **H6**, we averaged closeness scores across each participant pair. Closeness in this sample ranged from 10 to 59 ($M = 29.9$, $SD = 11.0$). Pairs who were closer tended to complete the activity faster, but this difference was not statistically significant (Pearson's $r = 0.24$, $p = 0.265$). Similarly, teammates who were closer tended to be more willing to change their item rankings, but this difference was not statistically significant (Pearson's $r = 0.345$, $p = 0.098$). We additionally split the pairs into "close" and "acquaintance" categories using the same 29.7 threshold as before; an ANCOVA (between-subjects factor: pair closeness; covariate: averaged pair videogame experience; dependent variable: team ranking accuracy) revealed a statistically significant main effect of relationship closeness ($F(1,21) = 4.90$, $p = 0.038$) and videogaming frequency ($F(1,21) = 5.61$, $p = 0.027$). This finding supports the hypothesis that closer friends can work together *more effectively* using telepresence.

7 DISCUSSION

A key finding of this work is that relationship closeness significantly influences how much people personalize telepresence robots and how long they spend on collaborative tasks. Relationship closeness also positively affects how present robot operators feel when they interact with others via the robot. In this sense, our results revealed that *relationship closeness matters more than any of our other considered predictor variables*. For co-present participants, relationship closeness did not affect most presence ratings, although closer friends felt less like they were seeing their partner when they looked at the robot. This insight can help to guide the effective use of telepresence robots.

7.1 Design Implications

Our results suggest that relationship closeness is a particularly important dimension to consider when designing and deploying telepresence robots. If the interactants have a close relationship, it is likely that remote participants will experience a stronger sense of presence in the remote space, regardless of whether or not the robot is personalized. Videogaming experience also seems to have positive effects for robot operators' sense of presence via a telepresence robot. On the other hand, co-present participants perceive the remote robot operator's presence similarly regardless of pre-existing relationship. Knowing these kinds of individual and social relationship variables can help us to predict how well a telepresence robot might help robot operators feel like they are "there" in the remote environments.

In the context of remote classroom participation, remote students might feel a stronger sense of presence in the classroom if they are able to sit close to and interact more with close friends (as opposed to other students or teaching assistants who do not have a close relationship with the remote student). Remote co-workers might feel a stronger sense of presence in the workplace if they are able to sit close to and interact more with their close colleagues (as opposed to wherever it is convenient to place the charging station). Likewise, if a new employee plans to telecommute, their orientation should involve in-person bonding with coworkers so they will feel more present in later work interactions. These insights can influence the ways family members use telepresence as well; for example, placing the physical robot hardware in the home of the less close family member (e.g., children who do not yet have strong memories of grandparents/uncles/aunts) may help remote robot operators (e.g., the grandparents/uncles/aunts themselves) feel more present without detracting from the co-present interactant's experience.

7.2 Limitations and Future Work

As with all studies in controlled laboratory settings, this research has limitations that could be addressed in our future work. First, the 60- and 90-minute durations of the studies may lead to different outcomes than long-term telepresence studies involving personalization. Additionally, we relied on the telepresence robots and robot operator computers being connected to high-speed university networks to achieve good connections to the robots. Such conditions may not apply when deploying telepresence systems in everyday environments with limited or inconsistent wireless internet services. As we look toward long-term deployments of telepresence robots in everyday settings, it will be important to consider longer-term timeframes and real-world environments.

Although we included personalization options motivated by past work and allowed participants to bring their own personalization items, Study 1 did not cover the full scope of possible telepresence personalizations. This work explored personalization in greater depth than previous telepresence robotics work, but additional personalization options remain, especially as only 47% of participants brought or used their own items. The time limits in Study 1 may have also affected participant performance. In Study 2, the broad age range is a potential limitation. However, one pair (aged 81 and 59) was an outlier; all other participants were aged 18-36, and excluding the oldest pair does not affect the results. The range of relationships considered was broader but still not all-encompassing; in particular, future work could involve more individuals with romantic relationships. Recent studies have addressed how telepresence robots are being used in long-distance relationships [31], one domain where operator and co-present person experience could be quite different than in less intimate relationships such as those found in classrooms or workplaces. Studying different use cases along the spectrum of relationship closeness will likely reveal differences and new insights in terms of telepresence robot system design to support various types of interpersonal relationships and interactions.

7.3 Conclusions

The goal of our first study (Study 1) was to examine the potentially positive effects of personalizing telepresence robots in order to improve robot operators' sense of presence via robot personalization. Our results did not demonstrate that personalization improved robot operator sense of presence, but the findings did show that the pre-existing closeness level of participant pairs significantly impacted the study experience. More relationship closeness was correlated with spending more time personalizing the robot, and closeness increased how present the remote participants felt while using the telepresence robot. More frequent videogaming also seemed to increase robot operator sense of presence via the robot. Our follow-up study on effects of relationship closeness (Study 2) confirmed the increased presence feelings of robot operators who are closer friends with individuals co-present with the robot. Together, these findings showed support for some, but not all, of our research hypotheses. The results reveal a rich picture of variables that affect how people experience telepresence robot use that will inform future research in this domain.

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