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Presentation of (Telepresent) Self: On the Double-Edged Effects of Mirrors

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Abstract— **Mobile remote presence systems present new opportunities and challenges for physically distributed people to meet and work together. One of the challenges observed from a couple of years of using Texai, a mobile remote presence (MRP) system, is that remote operators are often unaware of how they present themselves through the MRP. Problems arise when remote operators are not clearly visible through the MRP video display; this mistake makes the MRP operators look like anonymous intruders into the local space rather than approachable colleagues. To address this problem, this study explores the effects of visual feedback for remote teleoperators, using a controlled experiment in which mirrors were either present or absent in the local room with the MRP system (*N*=24). Participants engaged in a warm-up remote communication task followed by a remote driving task. Compared to mirrors-absent participants, mirrors-present participants were more visible on the MRP screens and practiced navigating longer. However, the mirrors-present participants also reported experiencing more frustration and having less fun. Implications for theory and design are discussed.**

Index Terms—**Mobile remote presence, telepresence, human-robot interaction, presentation of self, mirrors, self consciousness**

I. Introduction

Face-to-face communication enables people to use body language and gestures to communicate and interpret messages. Now, more than ever, "face-to-face" encounters can happen remotely. Friends and family can informally video chat using mobile devices in the palms of their hands (e.g., videochat) and large companies can broadcast meetings with large video conferencing systems (e.g., telepresence meeting rooms). Persistent video conferencing stations have been shown to encourage satellite workers to participate in meetings and to increase affinity toward remote sites [1,2], and a new class of products, mobile remote presence (MRP) systems, are allowing remote workers even greater opportunities to be members of the local office environment.

A. Mobile Remote Presence

Mobile remote presence (MRP) systems aim to support remote communication and collaboration in new ways. Such systems include PEBBLES [3], which enables sick children to participate in school classroom exercises; the PRoP [4] and Robatars [5], which enable operators to wander around and talk with others from a distance; the BiReality [6], which provides immersive user interfaces for remote operators; and the MeBot [7], which affords more socially expressive gesturing. Less mobile systems include the Hydra [8], which supports awareness and casual interaction; the CAVECAT [9], which enables collaboration across offices; and the ESP system [1], which enables satellite workers to engage with hub work teams. Commercial MRP systems include the Giraffe, QB, RoboDynamics TiLR, vGo, InTouch RP7, Double, and Beam.

The current MRP system, our Texai Alpha prototype, enables our co-workers to telecommute to work in California from their homes in countries around the world. In this system, the Texai operator communicates through Skype video chat. The operators also have the ability to move the robot as if they were walking around a room, find and approach individuals they need to speak with, and engage in both formal meetings and impromptu conversations. In a longitudinal study of Texai Alpha prototype usage in several companies that used field observations, critical incident interviews, and surveys, we observed that these systems can and do support informal communications and connections between distributed co-workers [2,10].

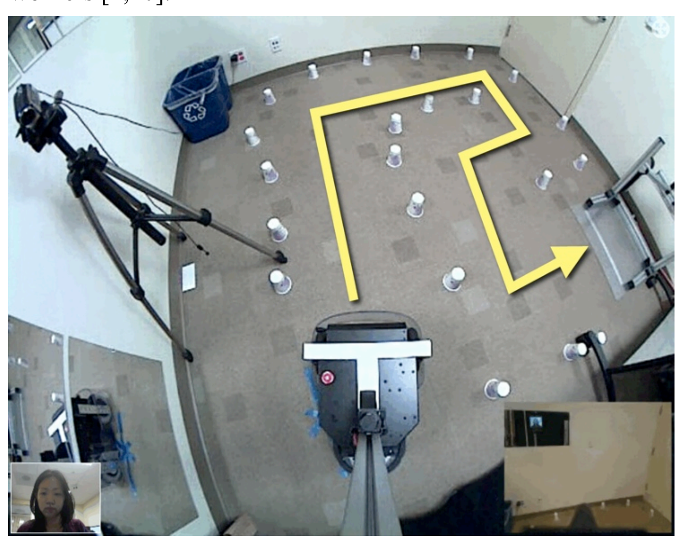
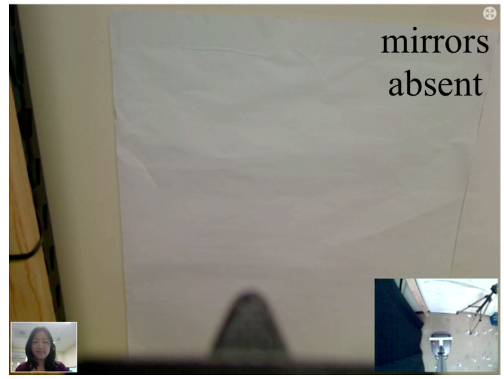


Figure 1. Lab environment as seen by experiment participant via Texai Alpha prototype (navigation view), positioned at the starting point of the obstacle course. The operator's view of herself is in the lower left picture-in-picture (PIP). The view through the head camera is in the lower right.

(2a)



(2b)

Figure 2. Mirrors-present (a) vs. Mirrors-absent (b) views as seen from the remote operator's perspective (i.e., participant's perspective).

A major problem arises when the remote operators (i.e., the remote operators of the MRP systems) do not present themselves visibly (e.g., a dark silhouette against a bright window) in the MRP system screen; when this happens, they can seem like anonymous robotic intruders into the local space. This simple mistake can make the MRP system seem like an intimidating surveillance machine as opposed to being an approachable communication device (as intended).

As discussed at a recent workshop at HRI 2011 on social robotic telepresence [11], there are many technical and social issues to address in this space, including (1) mechanical design, (2) user interface design, (3) interaction between the remote and local people, and (4) perceptions of the systems themselves.

While the current study did not study mechanical aspects of MRP design, it did focus on one specific prototype of a user interface design that aimed to improve the way that remote operators present themselves through the MRP system so that they will be more visible to local interactants. The implications of the user interface feature affect both the interactions between local and remote people, and the perceptions of the system.

B. *Issues in Remotely Presenting Oneself*

As technologies become an intrinsic part of one's presentation of self [12], it is becoming increasingly important for people to gauge how they are presenting themselves through these remote presence systems. Just as you select the clothing, shoes, and accessories that you wear to work, remote workers can select which media they use to be present in the workplace (e.g., phone, video conferencing, MRP systems) and how they will present themselves through those media.

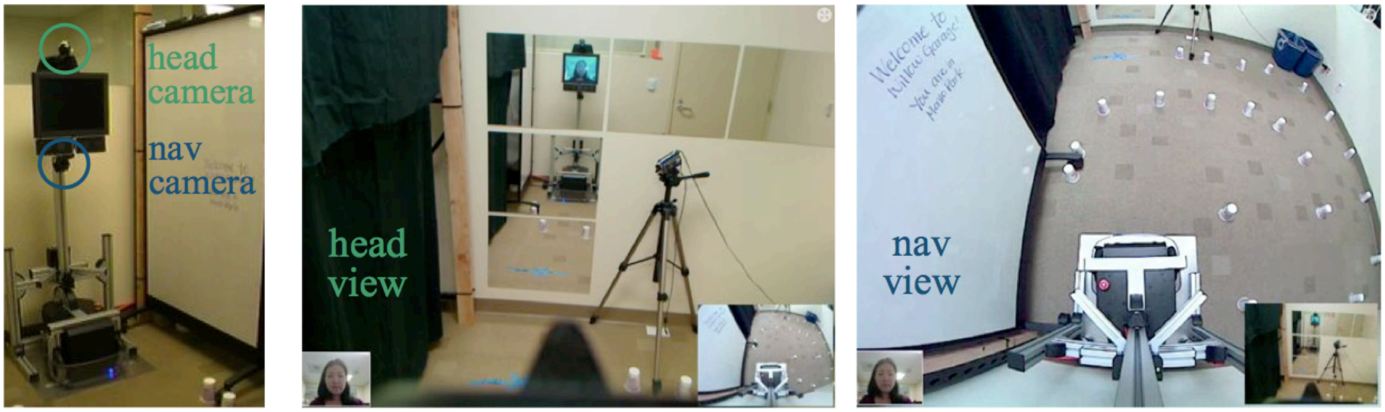
During the past couple of years of using the Texai MRP systems, we have observed several people telling remote operators, "You look terrible!" when the people are actually noticing that the Texai probably has a poor network connection, the result of which is unclear video. Just as phone calls with static and drop-outs can be disruptive to the flow of work [15], network latency and unsynchronized audio and video streams are common problem that jar communication. An often overlooked problem is the quality of the video image, including lighting, positioning, and gaze alignment. We hypothesized that operators would notice and improve their MRP self-presentation if they had more visual feedback, addressing the following research question: How does increased visual feedback influence the MRP operator self-presentation and user experience?

The most obvious way to show users how they appear is to display their own self-image in a mirror. It is common practice to use mirrors in product demonstration rooms for showing operators what they look like, e.g., InTouch, AnyBots, Willow Garage, Suitable Technologies. An earlier attempt at providing visual feedback included increasing the size of the operator's picture-in-picture (PIP) self-image, but this occluded the operator's view of the local environment, which made it difficult for operators to drive safely. Another attempt was made to provide a large initial self-image view at the beginning of the log-in process, but we still struggled with operators quickly forgetting about trying to be clearly visible over the full duration of interactions with locals. Because of these challenges, we opted to use physical mirrors in the local environment to increase operator's visual feedback.

Increasing self-directed attention is known to increase one's increased self-awareness [16]. Seeing oneself on video allows users to see themselves and make adjustments that they might not have otherwise known were needed. This is most evident with athletes [17] and dance performers [18], who rely on mirrors and video to understand their own movements and aid learning; however, the presence of mirrors in the environment does not always help with performance (e.g., pilates training) [19]. In virtual worlds, people who see their own self-representations (avatars) in virtual mirrors not only become more aware of their sense of self, but also behave differently towards others, depending upon the attractiveness and height of their avatars [13]; they will even exercise more if they see their avatars losing or gaining weight [14]. From the results of prior studies, we formulate the first hypothesis:

> HYPOTHESIS 1: With visual feedback, operators will be more aware of how they look and will work harder to improve their presentation of self.

However, self-awareness is a double-edged sword. Increased self-awareness can also lead to heightened awareness about one's appearance [20] and processes of performance



(3a) (3b) (3c)

Figure 3. Texai system from the local's perspective (a), circling the head and navigation cameras. Head view (b) vs. navigation (c) view from the remote operator's perspective (i.e., participant's perspective).

[21], which can have negative effects upon one's experience in the situation. This heightened awareness sometimes results in "choking under pressure" [22], which refers to performing poorly (relative to one's own skill level) when experiencing a lot of performance pressure. This leads us to a second hypothesis:

> HYPOTHESIS 2: With visual feedback, operators will feel self-conscious and have a less pleasant experience than those without.

Starting from these research questions and hypotheses, the current study explores the impact of visual feedback (as a user interface feature) upon the operator's user experience and the operator's behavioral performance in terms of how much effort she or he puts into using the system well, i.e., being visually easy to see for the locals and practicing driving the MRP system safely.

II. STUDY DESIGN

Using a between-participants experiment (visual feedback: mirrors present vs. mirrors absent), we tested the two hypotheses. Thus, each participant experienced only one of the two possible experiment conditions. Participants either saw mirrors on the walls (mirrors-present) or saw walls covered with paper to hide the mirrors (mirrors-absent). See Figure 2.

Each participant engaged in a communicative task with the experimenter (because communication is the primary use case for these MRP systems) and a navigation task of driving through an obstacle course (because safely and efficiently driving around is another use case for these MRP systems).

A. Participants

Twenty-four adult volunteers (ages: 19-45 years, *M*=27.6, *SE*=1.8) participated in the study for course credit or gift certificates worth $10. Participants were randomly assigned to an experiment condition; twelve women and twelve men were balanced across conditions.

B. Apparatus

As described in recent work [2,23], the Texai Alpha prototype stands approximately 1.6 meters tall and includes a mobile base, which carries a battery, touch screen, microphone, speakers, pan-tilt web camera, wide-angle camera, wireless router, and two laser range finders. The entire system can be controlled by a remote operator. Remote operators can drive the Texai Alpha prototypes into charging stations (to recharge the batteries) and drive away from the charging stations without assistance. When fully charged, the system can be operated for approximately eight hours. At the time of the current study, its top speed was set to 1.5 miles per hour.

The Texai remote presence system used for this study (Figure 3a – local's view) was operated through a web-based interface. The pan-tilt head camera allowed participants to have an eye-level view of the room, seeing the experimenter and the room walls (Figure 3b – operator's "head cam" view). Participants also used the navigation view to see the floor, using a static wide-angle camera that pointed toward the ground (Figure 3c – operator's "nav cam" view).

C. Lab Environment

The lab environment consisted of an obstacle course, mirrors on the walls that faced the Texai Alpha's charging station, and a digital video camera for recording the behavioral performance of each participant.

The obstacle course was a path through an office space that was outlined by white paper cups. See Figure 1. The yellow line (with arrow head) depicts the path through the obstacle course, beginning at the starting line and ending at the charging station. This line was not visible to participants in the study. During the instruction period, the experimenter demonstrated this path by walking through the obstacle course on foot.

D. Procedure

Participants' sessions were divided into three stages: joining the experiment and hearing instructions, doing a creative communication task, and completing a pair of navigation tasks – practice rounds and their final test round.

1) Joining the Experiment

Participants volunteered to use a web-based interface to log into the Texai MRP system from their own home or office computers. They did not physically come into the lab space. The web interface allowed participants to operatethe MRP system using mouse and keyboard controls. Participants also logged into a Skype account so they could use the video chat capabilities to see the experimenter and the experimental room. Once participants successfully logged in, the experimenter provided additional instructions about how to use the interface to operate the MRP. Participants were told to expect a couple of structured tasks that they should attempt to complete as best as possible.

In order to strengthen the experimental manipulation for the mirrors-present participants, they were also informed that "These mirrors on the wall are here so you know what you look like on the robot." The mirrors-absent participants were not told about any mirrors being present in the lab space.

2) Communication Task

For the communication task, participants were asked to complete a verbal creativity task. In this creativity activity, participants generated alternative uses for everyday objects — a shoe, key, bed sheet, and chair (similar to [24]). Participants had one minute to say aloud as many alternative uses as they could for each object. An example alternative use for a shoe would be using it as a flower pot.

The goals of the task were two-fold. First, the task allowed participants to warm up and get used to talking through the MRP system. Second, the task provided a scenario in which participants could engage in conversation with the experimenter while being exposed to the experiment manipulation (mirrors-present vs. mirrors-absent).

3) Navigation Task

After the creativity task, the experimenter directed participants to switch from the head view (looking upward) to the navigation view (looking downward) so that the participants could better see the obstacle course. Participants started practicing navigating the obstacle course (see Figure 1) and were allowed to practice for as long as they wished.

Once participants felt ready to do the final test drive, they went to the starting line of the obstacle course. The experimenter timed participants completing one loop of the course. Immediately after the timed drive, participants completed an online questionnaire and were debriefed about the purpose of the study. We also answered any questions from participants at that time.

E. Measures

1) Practice Rounds

In preparation for operating through an obstacle course, participants were allowed to practice driving through the course as many times as they wanted. We counted and recorded the number of practice rounds each participant completed.

2) Test Performance

When the participant told the experimenter that she or he was ready to do the final obstacle course run, the experimenter timed the participant's run from start to finish (minutes and seconds) and counted the number of cups that the participant accidentally pushed.

3) Frustration and Fun

Frustration and fun were gauged in a questionnaire. Participants were asked the following question: "For each word below, please indicate how well it describes your experience with the Texai." Participants then rated their attitudes on a Likert scale, ranging from 1 (describes very poorly) to 5 (describes very well).

4) Noticing Appearance

In the same questionnaire, each participant was asked: "Did you notice what you looked like during the study?" Their response options were 1 ("no, not at all"), 2 ("somewhat"), or 3 ("yes, definitely"). All participants could actually see themselves in the Skype picture-in-picture (bottom left corner in Figures 1, 2, 3), but we wanted to capture which participants noticed. Because noticing one's appearance is affected by how much a given individual is publicly self-conscious, we ran a linear regression analysis on how mirrors-present and individual public self-consciousness affected how much people noticed their appearances.

5) Appearance

Screenshots from each participant's video were taken at zero, two, and four minutes into the study session to calculate an average score of how well the participant presented herself or himself through the MRP system display (i.e., how visible was the participant). Two independent coders, who were blind to the experiment conditions, rated each screenshot in terms of the quality of the operator's on-screen appearance.

This appearance rating was an overall assessment of the image, taking into consideration four separate features: lighting, vertical positioning, horizontal positioning, and operator distance from the camera. Screenshot lighting was considered good if both the operator's face and background were well illuminated. However, if the operator or the background were so dark that elements in the image could not be discerned, then the screenshot would be thought of as having extremely bad lighting. Similarly, if an image were so bright that the images appeared whitewashed, it was considered to have bad lighting.

The other three features of the appearance assessment related to the positioning of the operator. A vertical positioning judgment reflected how well the head and torso appeared vertically in the screenshot. A good vertical position equated to the head positioned slightly above the middle of the screen, with some of the torso visible as well (as recommended by prior work in videoconferencing [25]). Screenshots with poor vertical positions had the head at the edges of the screen, and in extreme cases, partially cropped off. Similarly, horizontal positioning, evaluated how well the operator was centered horizontally. The more the operator appeared off to one side (either the left or the right), the more the horizontal positioning was considered poor. Lastly, the operator distance from the camera was considered good if only the head and torso were visible in the image. If too much of the body was visible, the operator would be considered inappropriately far from his/her camera. Many operators had the opposite problem (e.g., Figure 4 “5/somewhat good” image), and placed themselves so close to their cameras that their head filled the majority of the image and was cutoff.

The images were rated on a seven-point scale that accounted for all four features: 1=extremely bad; 2=bad; 3=somewhat bad; 4=so-so; 5=somewhat good; 6=good; 7=extremely good. The inter-rater reliability was good (*Pearson* r=.74). The scores for each participant were averaged across raters and across each of the three screenshots taken per participant. See Figure 4 for examples of screenshots that received ratings of 1, 3, 5, and 7.

F. Demographics

There are many individual differences (e.g., personality types) that could influence the dependent variables mentioned previously. As noted in the discussion around the hypotheses, the two variables that were of most interest in this context were public self-consciousness and self-monitoring. We used standardized scales from social psychology to measure each participant’s levels of these variables. Our working definition of public self-consciousness was the awareness of self as it is viewed by others [26]. Our working definition of self-monitoring was the extent to which people regulate their self-presentation relative to immediate situational cues [27]. We also asked standard demographics quesitons regarding age, gender, etc.

III. Analysis

Because this was a between-participants experiment design with two experiment conditions, we used an analysis of variance (ANOVA) for testing the effects of the mirrors being present vs. absent (independent variable) upon each of the dependent variables of interest (number of practice rounds completed, test performance, feelings of frustration and fun, and looking good to locals). To test for relationships between the dependent variables, we used Pearson correlation calculations. To test for effects of mirrors being present vs. absent and individual levels of public self-consciousness upon how much participants noticed their own appearances, we used a linear regression model (since all factors were continuous, not ordinal). For tests of statistical significance, we used a cut-off value of p<.05. Mean and standard error values are provided where appropriate.

IV. Results

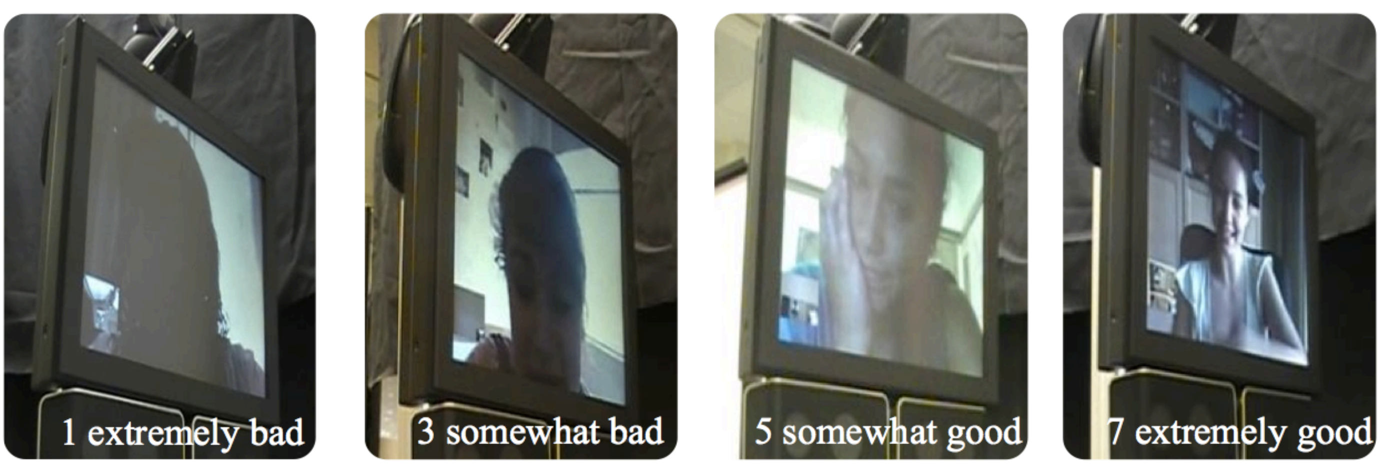
A. Practice Rounds and Test Performance

Participants in the mirrors-present condition drove nearly twice as many practice rounds (M=1.9, SE=0.25) as participants in the mirrors-absent condition (M=1.0, SE=0.09), F(1,22)=5.86, p<.05. See Figure 5a.

Although the number of practice rounds did not significantly affect the ultimate test performance (i.e., how quickly and accurately people ran the obstacle course), the relationship between number of practice rounds and speed of test performance approached statistical significance, F(1,22)=3.42, p=.08. It did not affect accuracy of the test performance (i.e., number of cups accidentally pushed), F(1,22)=0.17, p=.68. Test speed and accuracy were not found to be significantly correlated, *Pearson* r=.25, p=.24.

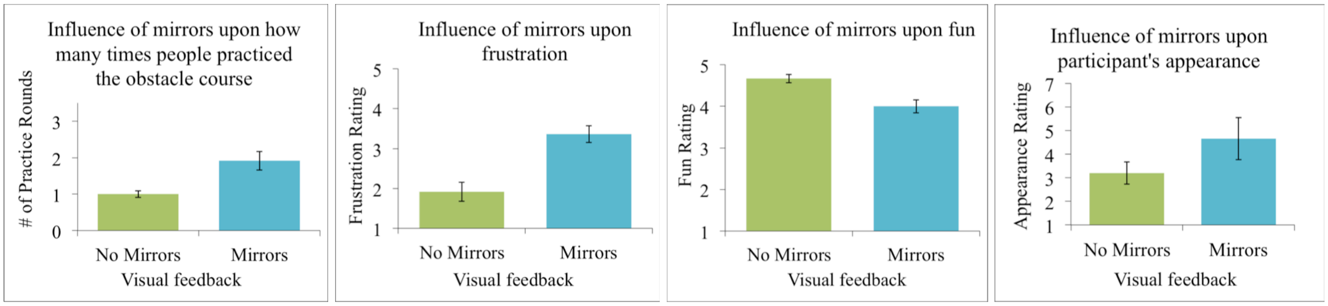
B. Frustration and Fun

Participants in the mirrors-present condition experienced more frustration (M=3.4, SE=0.2) than participants in the mirrors-absent condition (M=1.9, SE=0.2), F(1,21)=9.91, p<.01. Similarly, participants with mirrors had less fun (M=4.0, SE=0.16) than participants who did not see the mirrors (M=4.7, SE=0.10) F(1,21)=6.18, p<.05. See Figures 5b and 5c.



(4a) (4b) (4c) (4d)

Figure 4. Examples of participants as they presented themselves through the MRP display, showing participant screen shots that received scores of 1, 3, 5, and 7 along the seven-point scale. The mirrors-absent participants (a) were often too dimly lit to see or were off-center and/or awkwardly cropped in the MRP display. The mirrors-present participants (b) were often well lit and centered in the MRP display.



(5a) (5b) (5c) (5d)

Figure 5. Mean and Standard Errors for Influence of Mirrors Upon (a) Practice Rounds, (b) Frustration, (c) Fun, and (d) Appearance

C. *Noticing Appearance*

The linear regression analysis on how mirrors-present and individual public self-consciousness affected how much people noticed their appearances showed that both having mirrors present (β=*.60*, *p*<.05) and one's own public self-consciousness [26] (β=.07, *p*<.05) increased how much one's appearance was noticed (model *F*(2,20)=4.21, *p*<.05; goodness of model fit, R^2=0.3, adjusted R^2=.23).

D. *Appearance*

The two independent coders rated participants with mirrors present as looking better (*M*=4.65, *SE*=0.80) than participants without mirrors (*M*=3.19, *SE*=1.62), *F*(1,22)=7.82, *p*<.05. See Figure 5d.

E. *Demographics*

In this sample of participants, public self-consciousness [21] levels were average (*M*=12.3, *SE*=0.91) and self-monitoring [22] levels were relatively low (*M*=9.21, *SE*=0.71).

V. Discussion and Conclusions

These results provide support for both hypotheses. Operators with mirrors looked significantly better (i.e., were more visible) than operators without mirrors, supporting Hypothesis 1. Those operators with mirrors also practiced the obstacle course more and noticed what they looked like more than operators without mirrors, which is consistent with the finding that people who see themselves perform are more aware of their flaws or errors.

The presence of the mirrors may have had positive implications for participant behavior, but it also negatively impacted the participants' experiences. Mirrors-present participants felt more frustrated and had less fun than the participants who did not see any mirrors, supporting Hypothesis 2.

The finding that having visual feedback affects operator attitudes and behaviors is consistent with extensive research in human-computer interaction that has explored how seeing one's avatar influences one's attitudes and behaviors, not only in the virtual world, but also offline interpersonal interactions [13] and even how much they exercise [14].

Despite the fact that the local picture-in-picture view was present across both experiment conditions (see Figure 1, bottom left corner of each screen shot), we still found that these mirrors in the room made significant differences in people's behaviors and experiences. We conclude that it is not sufficient to provide a small picture-in-picture view of oneself to get the types of effects that we have seen in this study.

The presence of mirrors was not found to significantly affect task performance, which is what one might have predicted [21]. Although we had hoped that the increased amount of effort put into practicing the obstacle could ultimately improve the operators' ability to perform on the obstacle course test (in terms of time to task completion or in terms of the mistakes), we were not entirely surprised to find this in the results. There are stronger factors that influence Texai operator driving performance, which we have tested in a separate study [23], where we found that video gaming experience and an individual's locus of control (i.e., the extent to which people believe they can control events that affect them) were relatively strong predictors of how quickly people could drive through an office-like obstacle course. Because we were primarily interested in getting remote operators to present themselves more appropriately (i.e., be easier to see through the MRP system), we focused the current study upon the experiment manipulation that would most likely influence how much effort remote operators would put into their visual appearance.

A. *Implications for theory*

Just as one can adapt to and incorporate other technologies into one's presentation of self, it is also important to consider how one's presentation of self [12] is judged when remote presence systems are involved in interpersonal interactions. The current study demonstrated how providing visual feedback can influence how people feel, perform, and present themselves. Although additional effects of visual feedback were not explored in this study, it is foreseeable that operators' feelings (positive or negative) while operating a MRP system may transfer to their experience of interactions they have while operating, or to their evaluations of the MRP system itself. Also, the quality of the remote operator presentation may impact the how the local people perceive operator and interact with him/her.

Furthermore, variations on the mirror idea may temporarily draw the operator's attention to fix self-presentation issues without adversely affecting the user for the duration of their operating time. As mentioned previously, a quick reminder for the remote operator to check his/her image before connecting with the local participant would give the operator the opportunity to make adjustments before needing to focus on interaction or navigating the MRP system. A brief warning after the local participants and remote operator have connected could alert the operator to existing presentation issues without interrupting the interaction or persisting throughout the session. Finally, efforts to make the operator's video feed more salient may encourage a feedback cycle of checking the image and improving his/her appearance in the video display.

B. Implications for design

It will not always make sense to include such visual feedback to teleoperators, but this study provides empirical results that suggest situations where it would be advantageous versus disadvantageous to do so. A general design implication is that teleoperators can and will be affected by seeing mirror images of themselves while they are remotely operating robots.

1) To encourage more effort from remote operators

If your design goal is to improve how hard the teleoperator is trying to visually present herself or himself or to engage in more practice, then it is advantageous to provide mirror video images to the teleoperators. Examples of these situations might include training sessions for search and rescue [28], hostage negotiation, or firefighting [29] teleoperators, but not the actual missions if the visual feedback will increase cognitive load or distract from the primary task at hand.

More specific to mobile remote presence systems, this study's results suggest that presenting remote operators with visual feedback about their own appearances influences both how hard they try to look good and perform well in the MRP system. If your design goal is to make the MRP system look good (e.g., if you are a salesperson, trying to demo the MRP system to a local client), then it is better to provide lots of visual feedback to the remote operator of the MRP system. This should also be true for remote operators who are primarily concerned with how they appear to locals, but are less concerned about how uneasy they (the remote operators) feel. An example of this situation might be a doctor doing "telerounding," i.e., engaging in virtual bedside rounds at the hospital from remote locations [30].

2) To improve the user experience for remote operators

By contrast, if your design goal is to improve the user experience for the teleoperators (e.g., help the teleoperator feel more comfortable, have more fun, be less frustrated), then it is better to avoid providing large mirror video images to the teleoperators. Examples of these situations might include hosting tours for remote guests via an MRP system, e.g., TourBot at exhibitions [31] or facilitating a grandparent in visiting her grandchild across the country via an MRP or video conferencing system [32].

If your design goal is to make the remote operator feel good (e.g., if you are a salesperson, trying to demo the MRP system or other goods to a remote client [33] or a museum enabling remote visitors to tour the galleries via MRP system), then it is better to minimize the amount of visual feedback to the remote operator. One way to do this is to shrink the size of the picture-in-picture view of oneself; another way to do this is to show a large amount of visual feedback (in terms of screen real estate) at the beginning of the session, but to remove it after a few moments. This should also be true for remote operators, who are primarily concerned with how comfortable they feel and are less concerned with how they appear to locals.

VI. LIMITATIONS

As with any single experiment, the current study has many limitations. The explicit mention of the wall-mounted mirrors to mirrors-present participants is a potential confound that could be omitted from future studies; it was included as an explanation for why the walls were covered in mirrors. Because we did not record the amount of time that the participants looked at the mirrors (as we lacked gaze tracking), we do not know if a brief encounter with the mirrors is necessary for the effect or if prolonged gazing is necessary. We lacked a momentary self-consciousness measure, but felt that it would be too disruptive to the current set of tasks performed by these participants.

The artificiality of the task is another limitation that can be overcome. Because we wished to cleanly observe and measure task performance in this study, we chose a very structured communicative task (the creativity activity) rather than an open-ended discussion. Although this is less natural than the types of interactions that we have observed in the field [9], it is not entirely artificial; some MRP system field study participants have used these systems to conduct job interviews, which are also typically quite structured and involve one person doing the majority of the talking. Future work could focus upon more open-ended discussions. Although driving is an important part of MRP use, two-way communication is also a fundamental part of MRP use. As such, our future work will focus more upon communicative interactions rather, expanding this current work that focused upon driving and navigation.

VII. FUTURE WORK

Future studies can delve deeper into facets such as what individual differences may be in play, what set of task domains is most relevant to the context of communication via MRP system, and who is involved in interactions (e.g., dyads, groups). Considering individual differences, there might be differences between novice users with minimal remote communication experience and those users with a more substantial experience. A more expert population might start out with a better understanding of how to present oneself remotely, particularly ones who come from the television or movie production industries. Further research can also be conducted in other task domains, focusing on task performance and user experience on both the operator and local participants' side of the interactions, simultaneously. Finally, moving toward more interactive types of communication settings with dyads and groups will also provide for more natural and readily applicable design implications for these mobile remote presence systems, which are primarily used for communication in such groups.

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REFERENCES

[1] G. Venolia, J. Tang, R. Cervantes, S. Bly, G. Robertson, B. Lee, and K. Inkpen, "Embodied social proxy: Mediating interpersonal connection in hub-and-satellite teams," *Proc. CHI 2010*, ACM Press, 2010, pp. 1049–1058.

[2] M.K. Lee and L. Takayama, "'Now, I have a body': Uses and social norms for mobile remote presence in the workplace," *CHI 2011*, ACM Press, 2011, pp. 33–42.

[3] D.I. Fels, J.K. Waalen, Zhai, Shumin, and P.L. Weiss, "Telepresence under exceptional circumstances: Enriching the connection to school for sick children," *Proc. Interact 2001*, Tokyo, Japan: 2001, pp. 617-624.

[4] E. Paulos, "PRoP: personal roving presence," *Proc. SIGGRAPH 1997*, ACM Press, 1997, p. 99.

[5] H. Ishiguro and M. Trivedi, "Integrating a perceptual information infrastructure with robotic avatars: a framework for tele-existence," 1999, pp. 1032-1038.

[6] N.P. Jouppi, S. Iyer, S. Thomas, and A. Slayden, "BiReality: Mutually-immersive telepresence," *Proc. ACM Multimedia 2004*, ACM Press, 2004, pp. 860–867.

[7] S.O. Adalgeirsson and C. Breazeal, "MeBot: A robotic platform for socially embodied presence," *Proc. HRI 2010*, ACM Press, 2010, pp. 15–22.

[8] H. Kuzuoka and S. Greenberg, "Mediating awareness and communication through digital but physical surrogates," *Ext. Abstracts CHI 1999*, ACM Press, 1999, pp. 11–12.

[9] M.M. Mantei, R.M. Baecker, A.J. Sellen, W.A.S. Buxton, T. Milligan, and B. Wellman, "Experiences in the use of a media space," *Proc. CHI 1991*, ACM Press, 1991, pp. 203–208.

[10] L. Takayama and J. Go, "Mixing metaphors in mobile remote presence," *Proc. CSCW 2012*, 2012.

[11] S. Coradeschi, A. Loutfi, A. Kristoffersson, G. Cortellessa, and K.S. Eklundh, "Social robotic telepresence," Lausanne, CH: 2011, pp. 5-6.

[12] E. Goffman, *The Presentation of Self in Everyday Life*, New York: Anchor Books, 1959.

[13] N. Yee and J.N. Bailenson, "The Proteus effect: The effect of transformed self-representation on behavior," *Human Communication Research*, vol. 33, 2007, pp. 271-290.

[14] J. Fox and J. Bailenson, "Virtual self-modeling: The effects of vicarious reinforcement and identification on exercise behaviors," *Media Psychology*, vol. 12, 2009, pp. 1-25.

[15] N. Yankelovich, N. Simpson, J. Kaplan, and J. Provino, "Porta-person: Telepresence for the connected conference room," *Ext. Abstracts CHI 2007*, ACM Press, 2007, pp. 2789–2794.

[16] S. Duval and R.A. Wicklund, *A Theory of Objective Self Awareness*, New York: Academic Press, 1972.

[17] D.G. Liebermann, L. Katz, M.D. Hughes, R.M. Bartlett, J. McClements, and I.M. Franks, "Advances in the application of information technology to sport performance," *Journal of Sports Sciences*, vol. 20, 2002, pp. 755-569.

[18] K. Dearborn and R. Ross, "Dance learning and the mirror: Comparison study of dance phrase learning with and without mirrors," *Journal of Dance Education*, vol. 6, 2006, pp. 109-115.

[19] J.A. Lynch, G.R. Chalmers, K.M. Knutzen, and L.T. Martin, "Effect of learning a Pilates skill with or without a mirror, on performance without a mirror," *Journal of Bodywork and Movement Therapies*, vol. 13, 2009, pp. 104-111.

[20] S.A. Radell, D.D. Adame, and S.P. Cole, "Effect of teaching with mirrors on body image and locus of control in women college ballet dancers," *Perceptual and Motor Skills*, vol. 95, 2002, pp. 1239-1247.

[21] R.F. Baumeister, "Choking under pressure: Self-consciousness and paradoxical effects of incentives on skillful performance," *Journal of Personality and Social Psychology*, vol. 46, 1984, pp. 610-620.

[22] R.F. Baumeister and K. Vohs, "Choking under pressure," *Encyclopedia of Social Psychology*, Sage Publications, 2007, pp. 140-141.

[23] L. Takayama, E. Marder-Eppstein, H. Harris, and J.M. Beer, "Assisted driving of a mobile remote presence system: System design and controlled user evaluation," *Proc. ICRA 2011*, Shanghai, CN: 2011, pp. 1883-1889.

[24] J.P. Guilford, P.R. Christensen, P.R. Merrifield, and R.C. Wilson, *Alternate Uses Task Manual*, Sheridan Psychological Services, 1978.

[25] D.T. Nguyen and J. Canny, "More than face-to-face: empathy effects of video framing," *Proceedings of CHI 2009*, ACM Press, 2009, pp. 423-432.

[26] M.F. Scheier and C.S. Carver, "The self-consciousness scale: A revised version for use with general populations," *Journal of Applied Social Psychology*, vol. 15, 1985, pp. 687-699.

[27] M. Snyder, "Self-monitoring and expressive behavior," *Journal of Personality and Social Psychology*, vol. 30, 1974, pp. 526-537.

[28] R.R. Murphy and J.L. Burke, "From remote tool to shared roles: Human-robot interaction in teleoperation for remote presence applications," *IEEE Robotics and Automation Magazine*, 2008, pp. 39-49.

[29] K. Schilling and L. Preucil, "Tele-presence methods supporting cooperation of robots and humans," *International Workshop on Safety, Security, and Rescue Robotics*, Kobe, Japan: 2005, pp. 207-211.

[30] M. Ifthikar and M. Muralindran, "Otorob (Ortho robot) with Docmata (Doctor's eye): Role of remote presence in developing countries," *International Conference on Advances in Human-Oriented and Personalized Mechanisms*, 2009, pp. 51-56.

[31] P. Trahania, W. Burgard, A. Argyros, D. Hahnel, H. Baltzakis, P. Pfaff, and C. Stachniss, "Tourbot and WebFair: Web-operated mobile robots for tele-presence in populated exhibitions," *IEEE Robotics and Automation Magazine*, 2005, pp. 77-89.

[32] J.M. Beer and L. Takayama, "Mobile remote presence systems for older adults: Acceptance, benefits, and concerns," *HRI 2011*, ACM Press, 2011, pp. 19–26.

[33] J. Hwang, S. Lee, S.C. Ahn, and Y. Kim, "Augmented robot agent: Enhancing co-presence of the remote participant," *IEEE International Symposium on Mixed and Augmented Reality*, Cambridge, UK: 2008, pp. 161-162.