Double Trouble: The Effect of Eye Gaze on the Social Impression of Mobile Robotic Telepresence Operators

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Abstract. Eye gaze is used to convey crucial information during interactions with humans and robots. Modern video conferencing systems, an aspect of mobile robotic telepresence (MRP) systems, have limited eye gaze functionality due to the Mona Lisa effect. This paper compares the effects of eye gaze during brief interactions with MRP operators. In an online between-subjects study (N = 79), participants viewed a video of a hallway encounter between a passer-by and an MRP system; the operator either used or did not use mutual gaze. We used an observer 'trick' to study the effect cheaply. Results showed that participants' social impressions of the MRP operator were higher when the operator used versus did not use mutual gaze, showing that eye gaze can lead to an improvement in social perception even in a seemingly insignificant encounter such as a hallway passing. We argue for the importance of social acknowledgment cues to improve impressions of telepresence operators and to make mingling smoother and social roles more balanced. We describe potential opportunities for technological innovation in MRP systems and propose research directions to extend this work.

Keywords: Mobile Robotic Telepresence · MRP · Eye gaze · Workplace · Social impression · Operator

1 Introduction

Mobile Robotic Telepresence (MRP) systems (also referred to as telepresence robots) are being increasingly used at conferences, workplaces and public spaces to allow geographically dispersed individuals to interact with remote people and objects [12]. MRP systems typically host a live video of a remote operator on a flat screen which is attached to a steerable base, thereby enabling the driver, referred to as *operators* or *teleoperators*, to join meetings, attend presentations, and socialize from a remote location [15, 23, 30]. Commercial MRP systems include the Double robot (http://www.doublerobotics.com) and Beam robot (https://www.suitabletech.com).

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Past work has acknowledged limitations in social interaction that is mediated by MRP systems (e.g. [19, 20, 23]. However, literature in HCI and HRI on usability issues with MRP systems primarily focuses on validating the usefulness of existing capabilities such as the system's mobility (e.g. [22]), field of view (e.g. [9]), system height (e.g. [24]), and appropriate volume settings (e.g. [10]) rather than the social behaviours that operators could achieve with advances in MRP systems.

Here, we evaluate the effect of mutual gaze and smiling by an MRP operator during casual passing by to test whether social greeting cues in a person could help improve how operators are perceived by observers in their remote location. Following past work on observer perception [16], we specifically evaluate the impressions of *observers* of MRP systems rather than operators as done in most past work because a major theme in past studies with *operators* of MRP systems is that a primary concern of operators is how they are presented to others (rather than deficits in how others are presented to them) [20]. Because of this potential imbalance in lower impressions of remote compared to collocated persons [28], improving impressions of MRP operators is particularly important for balancing roles in interaction or collaboration via MRP systems.

We first break down two key aspects of MRP systems – tele-embodiment and video conferencing. We subsequently raise questions about the potential social effects of MRP systems in brief hallway encounters. The main contributions of this paper are an empirical study of eye gaze in MRP systems during passer-by scenarios and an inexpensive method to test it.

1.1 Tele-Embodiment

Several studies mention *embodiment* as an inherent characteristic of MRP systems [3, 12, 15, 18, 30]. MRP systems provide a physical embodiment for the operator, which has been referred to as *tele-embodiment*, and are generally found to be useful in supporting the operator's sense of presence in a remote location because they also afford the ability to move [30]. In particular, if remote locals have social expectations of acknowledgment by operators, then social acknowledgment may be an important design consideration for telepresence robots.

1.2 Video Conferencing

Although video conferencing systems are widely used across the globe, there are limitations which prevent it from completely replacing real-life interactions.

Eye Gaze. When a local directs their gaze towards the operator shown on-screen, it may not be clear that the operator is gazing back towards them. This is because the local essentially assumes the viewpoint of the operator's webcam, which is positioned above the operator's screen; the operator will normally look at the screen beneath the webcam during an interaction, meaning they will never actually look into the webcam and thereby toward the local. As a workaround, the operator can look into the webcam, giving the illusion that they are gazing directly towards the local. This can be tied to the phenomenon known as the Mona Lisa effect, where a subject on a flat medium appears to direct their gaze at observers regardless of where the observers are positioned. However, in normal video conference situations the Mona Lisa effect is not achieved if speakers look at the screen image of the listener, which is not the same location as the camera. It is this characteristic of video conferencing which makes eye contact particularly challenging [6]. Advanced robots such as the Furhat [1] include dynamic eye gaze and neck tilting through a back-projection onto the robot head, however this technology is meant for improving robot articulation and not human embodiment in video conferencing.

Lack of mutual gaze in human-human interaction has numerous effects. Fullwood [7] showed in his study that video-mediated partners were less likeable for the locally positioned participant compared to collocated partners, probably due to the attenuation of visual signals, in particular eye gaze. In another study, researchers found that participants who received averted eye gaze during a conversation felt ostracised and there was lower relational value [29]. In their study, Bayliss and Tipper [2] observed that faces who never looked to the subject were perceived as less trustworthy than faces who always looked to the subject.

We can also consider the operator a robot since they are tele-embodied in the robot itself. Research in human-robot interaction show similar findings regarding eye gaze behaviour. Mutlu et al. [17] observed that subjects who did not receive eye gaze from a robot at least once felt ignored, while Hoffman et al. [8] found that participants' social impression of robots that stayed focused towards the subject were higher.

Smiling. Since video conferencing systems put a limitation on eye gaze, operators may rely on other cues such as smiling to give a positive impression. Lau [13] found that participants rated a person in a video as more socially attractive when the person smiled compared to did not smile.

1.3 Brief, Path-Crossing Encounters: A (Niche) Scenario

Current literature on MRP systems typically looks at explicit, intentional and verbally communicative scenarios, e.g. walking up to the parked MRP system to ask the operator a question or interaction during meetings [12] without considering uses cases like non-verbal acknowledge during hallway passing. Kontogiorgos [11] examined embodiment effects in interactions with failing robots but did not consider hallway scenarios and did not use an MRP. However, MRP systems are normally parked in between use. From the first author's own experience in using the Double robot at work, the parking location is often not associated with the next use case, so when an operator logs in, they need to first drive to their next location. A notable exception is work by Neustaedter et al. [20], who found some evidence that passing events with MRP systems are not viewed favourably by locals. Therefore, additional HCI research could be done on niche yet possibly common use cases with MRP systems at the workplace, such as brief hallway encounters with colleagues.

Indeed, office environments pose a number of challenges for MRP systems, including understanding how social norms are affected. While moving around in hallways, it can be challenging for operators to engage in social interaction with locals due to the attention given to operating the system [12]. The limitation of video conferencing systems also means that the operator cannot use natural gaze cues as when they are locally present.

Yet emotional expressions are an important part of work interactions, and nonverbal cues either draw somebody in (e.g. eye gaze, smiling) or push them away (e.g. gaze avoidance, frowns) [9]. However, it is unclear whether this nonverbal behaviour may be important in a less formal situation such as hallway passing, rather than in direct conversation (as studied in past work).

1.4 Hypotheses

If MRP systems provide tele-embodiment for the operator, combined with the difficulty to experience mutual gaze, what effect might this have on the social impression of the operator during brief, path-crossing encounters? To our knowledge, there have been no previous controlled studies on eye gaze in MRP systems specifically for casual passing by. However, we can look to the aforementioned evidence in eye gaze literature, both in human-human and human-robot interaction, and hypothesize that MRP systems which support mutual gaze will result in higher social impressions of the operator:

H1 – Participants' social impression of the MRP operator will be higher in hallway encounters with mutual gaze versus without mutual gaze.

Additionally, it is not uncommon for colleagues to greet each other in the hallway. In our case, we operationalize greeting as a smile; no words are spoken. We hypothesize that a robot teleoperator who uses a greeting, in the form of a smile at the appropriate time, could improve the social impression of the operator:

H2 – Participants' social impression of the MRP operator will be higher in hallway encounters with a greeting versus without a greeting.

2 Method

To test our hypotheses, we conducted a 2 (mutual eye gaze: present vs. absent) $\times$ 2 (greeting: present vs. absent) between-subjects experiment with the dependent variable being *social impression*. The first independent variable was *eye gaze*. In addition to eye gaze, we added a second independent variable: *greeting*. Including conditions for both the presence and absence of mutual eye gaze and greeting allowed us to test for any interaction effects as well as account for any potential ceiling effects.

2.1 Wizard-of-Oz Videos

We recorded four videos of an observer walking past a telepresence robot in a hallway via a third-person camera angle. The scene plays out as follows: a telepresence robot navigates down a hallway; at the same time, an observer walks down the hallway in the opposite direction; eventually, the telepresence robot and the observer cross paths and an interaction takes place; both actors continue down the hallway in opposite directions (see Fig. 1).

We used an observer 'trick' as a wizard-of-oz approach to make it appear as if the robot supports mutual gaze functionality (see Fig. 2). For the conditions where there is no mutual gaze, we simply asked our actors to operate the robot as usual and either greet or not greet the observer with a smile. For the conditions with mutual gaze, we carefully

Fig. 1. Wizard-of-oz videos storyboard; depending on the assigned condition, shot 3 plays out differently.

choreographed the behaviour of the operator to create an illusion where it appears, from the third-person view, that the operator directs their gaze towards the observer. Note that this illusion is only possible due to the use of a third-person camera angle.

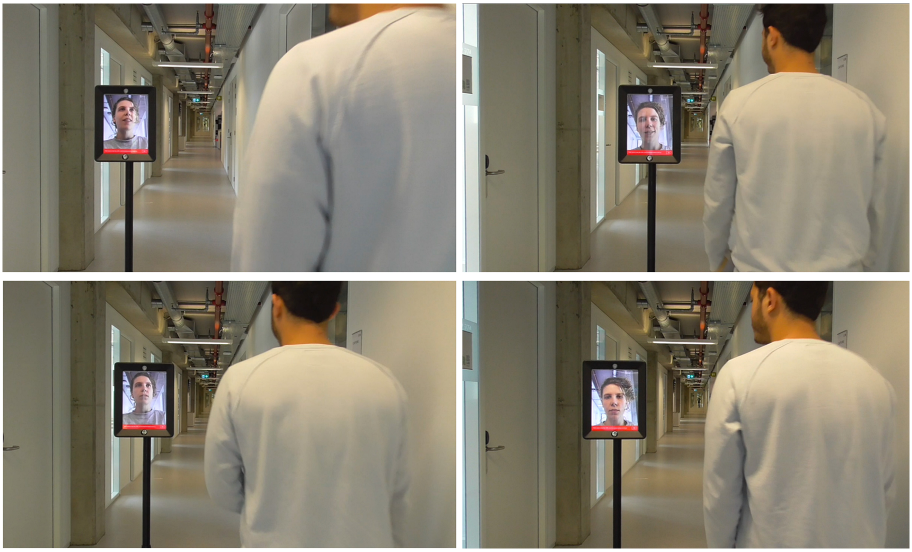

Fig. 2. Snapshot of each condition; top-left: cheerful greeting and gaze (C_G); top-right: cheerful greeting and no gaze (C_NG); bottom-left: no cheerful greeting and gaze (NC_G); bottom-right: no cheerful greeting and no gaze (NC_NG).

Each video scenario was 20 s long and played on repeat two times, resulting in a total of 60 s per video per condition. Audio was omitted entirely from all videos.

2.2 Task and Procedure

We used the Qualtrics platform (https://www.qualtrics.com) to generate a survey for our data collection. Before the start of the survey, the concept of telepresence robots is explained and an image of a Double robot is shown.

The survey begins by reading the following: "Scenario: You currently work at a multinational company, where your colleagues are spread around the globe. Your company has recently bought the Double Robot, so that offshore colleagues can be remotely present at your workplace. Instructions: Imagine you are walking down the hallway and experience the following scene (video on the next page)." The Randomizer feature on Qualtrics assigns the subject one of the four conditions. The subject then proceeds to watch the video and afterwards rates their social impression of the operator through a series of Likert-type questions. At the end of the survey, participants are asked to briefly describe in a few words their overall impression of the operator.

2.3 Measures

We break down social impression into four items: Rapport, Social Presence, Interpersonal Attraction and Trust. These four items were inspired by Daniel Roth et al. [26] (c.f., [2, 4, 21, 27]) who studied the effect of hybrid and synthetic social gaze in avatar-mediated interactions and who showed the relevance of these four items in relation to different types of gaze behaviour. For each of the four items, we prepared Likert-type questions on a scale from 1 (strongly disagree) to 7 (strongly agree). Rapport consisted of eleven questions, Social Presence consisted of six, Interpersonal Attraction consisted of six, and Trust consisted of three resulting in a total of 26 questions. Cronbach's α was very reliable for this scale (.93).

2.4 Participants

We recruited $N = 82$ participants through the Amazon Mechanical Turk platform (https://www.mturk.com). We used the built-in qualifications feature of MTurk to ensure that all participants resided in the United States, as well as required MTurk Master qualification. Participants were paid \$1.00 through the MTurk website based on MTurk conventions. Participants were provided with a unique code at the end of the survey as a prerequisite to receiving the compensation. Furthermore, the survey interface did not allow videos to be skipped, playing full length before proceeding to the next step.

3 Results

3.1 Outlier Removal

We noticed that one subject, for all 26 questions, responded with only end-point answers. For this reason, we declared the subject an outlier. To verify this, we used the Median Absolute Deviation method (MAD) which is known to be effective for small sample sizes ($n < 25$ for each of our four conditions). According to Leys *et al.* [15], a MAD rejection threshold of 3.0 is very conservative while 2.5 is moderately conservative and 2.0 is poorly conservative.

We found 2.5 to be effective in removing the 'end-point answers' participant and an eventual two more participants without further reducing the sample size, leading to a final sample size of $N = 79$. As a result, 19 subjects were assigned condition C_G, 22 subjects NC_G, 21 subjects C_NG and 17 subjects NC_NG.

3.2 Social Impression

A factorial analysis of variance (ANOVA) with Greeting and Mutual Gaze as factors was conducted in SPSS.

Greeting. The test yielded significant results, $F(1, 75) = 15.70$, $p < .01$. The social impression of the operator was rated higher by participants who viewed the 'with greeting' videos ($M = 4.98$, $SD = .96$) than those who viewed the 'no greeting' videos ($M = 4.17$, $SD = 1.02$).

Mutual Gaze. The test yielded significant results, $F(1, 75) = 5.67, p = 0.02$. The social impression of the operator was rated higher by participants who viewed the 'with mutual gaze' videos ($M = 4.81$, $SD = 0.99$) than those who viewed the 'no mutual gaze' videos ($M = 4.37$, $SD = 1.11$).

Interaction Effect. No interaction effect was found between the two variables, $F(1, 75) = .484$, $p = .489$ (Fig. 3).

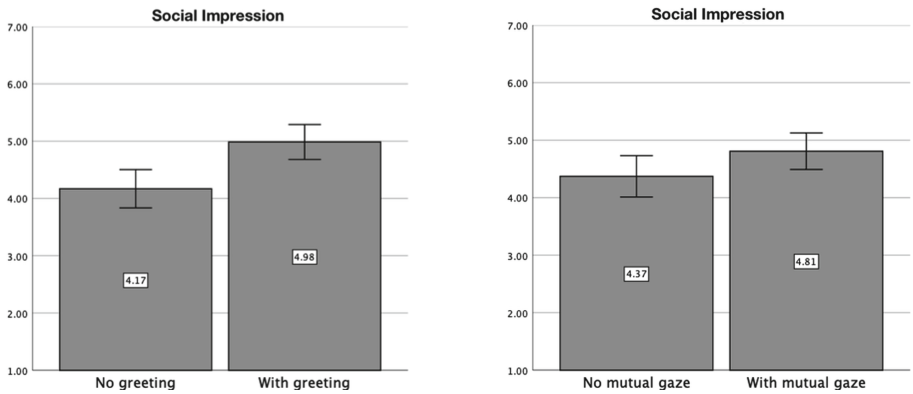

Fig. 3. Social impression of the operator vs. greeting (left) and mutual gaze (right).

4 Qualitative Results

To assess what people generally thought about each of the different conditions, we coded participants' responses to the open-ended question (where we asked them to briefly describe their impression of the operator) as 'positive', 'neutral' or 'negative' per condition. We present the findings organized by condition i.e., our consistent gaze and smiling conditions, then our inconsistent gaze and smiling conditions.

Consistent Gaze and Smiling Behaviour Resulted in Responses with Highest and Lowest Emotional Valence
The ‘no mutual gaze/no greeting’ video (NC_NG) yielded the most negative responses, including people thinking the operator was “bland”, “disinterested and oblivious”, “not friendly” or “cold and avoidant”. Some subjects appeared to feel intentionally ignored, e.g. “I feel like they were doing their own thing and didn’t want to be bothered” or “she ignored me”. Others seemed to assume the operator was simply not interested in them or had other things to do, e.g. “a little cold, but probably willing to talk and discuss”, “the operator seemed to be intent upon carrying out her tasks rather than engage in small talk”.

The responses to the ‘with mutual gaze/with greeting’ video (C_G) yielded the most positive results, e.g. “they were friendly and interactive”, “the operator seemed to be responsive and cordial”, “they seem like a typical employee”.

Inconsistent Gaze and Smiling Resulted in Responses with Mixed Emotional Valence
For the ‘no mutual gaze/with greeting’ video (NC_G), some of the more negative responses were “bland, uninterested”, “she was nice but standoffish and it felt awkward”, “cold”, “quite stoic and emotionless”. At the same time, there were also some positive responses, e.g. “friendly, approachable, receptive, and reciprocal”, “friendly, calm, busy”, “she seemed very friendly”. The negative and positive comments indicate that some individuals may be more influenced by the inclusion or lack of mutual gaze than others.

In a similar fashion, subjects had mixed impressions for the ‘with mutual gaze/no greeting’ video (C_NG): “cold and distant”, “nice and friendly”, “distant, uninteresting, preoccupied”, “she seemed interested, but not invested in my presence”, “…they seemed nice, acknowledged my presence, and I felt the urge to say hello to them”.

5 Limitations and Future Work

5.1 Limitations

Lack of Clear Manipulation Check. It is not explicitly clear whether subjects perceived mutual gaze in the videos. Some of their open responses provided evidence that the inclusion or exclusion of mutual gaze in the interaction was correctly conveyed -e.g., “*…she looked up*” vs. “*she ignored me*”. However, a more direct method of checking the manipulation may prove beneficial, e.g. directly asking participants whether the operator looked at them or performing another study to verify the manipulation in the video. Furthermore, the wizard-of-oz approach depended on an illusion only capable of being seen from a third-person view; it is not known whether subjects were able to fully empathize with the passer-by in the video.

Cultural Influences. Because we recruited participants through the MTurk platform, and used the built-in qualifications feature to only allow access to participants who resided in the United States, we assume that all participants are American and culturally identify as such. However, we cannot be fully certain that this is the case and therefore cannot be certain that all participants follow the same cultural norms or have the same values. Moreover, some MTurk workers inaccurately report their location of residence, which we attempted to address using MTurk's location filtering, but could use IP address filters.

5.2 Future Work

Social Acknowledgement Supported By Future MRP Technology. We did not build a functional MRP system to support mutual gaze or deliver social acknowledgement prompts to the observer. However, we note here a number of ways this can be done.

Teleprompter technology uses mirrors to allow TV hosts to read their script – which the mirror projects onto the camera lens – while looking directly into the camera at the same time. This technology is used to make it appear as if the TV host is looking directly at all viewers. MRP technology uses the operator's own computer for video conferencing, so implementing an additional teleprompter setup would not be a practical solution. However, there is growing research to integrate a smartphone's front-facing camera underneath the its screen, extending the screen real estate and allowing for 'all-screen' devices. This could (unintentionally) result in an experience closer to the Mona Lisa effect. Alternatively, modern artificial intelligence is able to swap out faces of people in existing videos with convincing realism, a technique known as *deepfake*. Apple attempted to 'fix' eye gaze in one of their iOS software updates, such that, for the observer on the end of a video call, the user on-screen would appear to be looking at the camera and therefore at the observer as if making eye contact [5]. Deepfaked eye gaze could be used with MRP operators as well. However, this would be a continuous gaze and is not the same effect as studied in our paper, where the operator switches between not looking at the observer to looking at the observer while using the device.

Other signals of eye contact or passer-by acknowledgment could be explored, such as flashing lights, a graphic overlay on the MRP's screen or an MRP system that can pan its screen/"head". The technology for these features is not impossible, and we invite researchers and designers to explore these possibilities.

Extending this Research. It would be interesting to explore whether our wizard-of-oz videos can be made in first-person view and displayed, for example, in a virtual reality system. This could enable subjects to feel more embodied in the role of the passer-by and therefore provide responses which are closer-to-life.

Finally, this research study looked at social impression in the broadest sense – are there specific social effects to be explored more deeply, e.g. the effect of mutual gaze on trust with MRP operators?

We believe this study can help address some previously identified issues about how MRP operators think others perceive them through a design-focused study. We hope that other researchers can pursue a variety of research directions that explore niche yet relevant design solutions to operators' concerns about telepresence devices as well as the technology development to realize those design solutions which seem promising.

6 Conclusion

We conclude from the statistical analysis that interactions with MRP operators in hallway encounters which support mutual gaze result in higher ratings of the operator's social impression than those which do not support mutual gaze. We also found from participants' qualitative short answers that they wrote more positively when both gaze and a greeting were present compared to absent, and more mixed answers when inconsistent cues were shown.

The theory pulled from both human-human and human-robot interaction provided strong evidence of the importance of eye gaze in social interactions; this work extends those findings to low-interactive hallway passing events, where our results suggest using eye gaze in hallways can be a strategy to broadly improve MRP appeal. Through a wizard-of-oz approach, we have shown how mutual gaze positively affects social impressions without having had to develop the technology beforehand. The video trick used in our study to simulate a mutual eye gaze action may be a feasible, low-cost solution for online studies, since some participants commented about the operator looking at the passerby. However, further work can be done to verify its convincingness. The actuation by a robot was also not tested, since the trick was to use an on-screen change rather than a robot's articulated gaze.

MRP systems are still evolving and it is unclear whether technological advancements in eye gaze or social acknowledgement will be made to these systems in the near future. In the meantime, our study shows the importance of considering the social effects of using MRP technology at the workplace. Although the general results of eye gaze with MRP systems is not novel, we have shown here that it applies to hallway encounters, too. Not everyone may be affected by the limitation of eye gaze, but the lack of mutual gaze in MRP systems may have the potential to hinder the forming of relationships between remote colleagues and limit team interaction in the long run.

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