Robot-Mediated Communication

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Abstract

Since telepresence robots began entering the US commercial market over a decade ago, telepresence robot-mediated communication (RMC) has become increasingly prevalent and relevant. In this essay, I describe key technological properties of telepresence robots, summarize findings regarding communication and social interaction through such robots, and propose a framework to guide future study of telepresence robot-mediated discourse and language use. In concluding, I reimagine how telepresence robots could be reconceptualized and redesigned, for example, by moving beyond human metaphors to incorporate "superhuman" attributes, and raise questions about the intended and unintended consequences of RMC.

WHAT IS ROBOT-MEDIATED COMMUNICATION AND WHY DOES IT MATTER?

As robots become increasingly common human helpers and companions, the study of human–robot interaction has surged in fields such as ergonomics, healthcare, education, and human–computer interaction. This includes interest in how people communicate with and through robots that are teleoperated by humans, or what in this essay is referred to as *robot-mediated communication* (*RMC*).

RMC is human–human communication in which at least one party is telepresent through voice, video, and motion in physical space via a remotely controlled robot (Herring, 2015).[1] Sometimes described as "videoconferencing on wheels" (Desai, Tsui, Yanco, Uhlik, 2011), RMC adds to real-time audio and video the ability of a person to navigate and move about in a remote physical location embodied as, or through the proxy of, a robot.[2] Because of the embodiment and enhanced control that they offer, particularly in terms of

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[1] Some categories of remotely operated robots, such as teleoperated service robots, robotic toys, and androids, typically do not include video. These are not considered to be RMC platforms in this essay.

[2] RMC is sometimes referred to as *embodied video-mediated communication* (*eVMC*; Tsui, Desai, & Yanco, 2012). Alternate names for telepresence robots that can be found in the literature include personal roving presence (ProP; Paulos & Canny, 1998), mobile remote presence (MRP; e.g., Takayama & Go, 2012), and mobile robotic telepresence (MRP; Kristoffersson, Coradeschi, & Loutfi, 2013).

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mobility, telepresence robots can provide a richer sense of "being there" than online videoconferencing technologies such as Skype. They enable a user not only to communicate at a distance but to be virtually "in two places at once."

The term *RMC* was coined by analogy with "*computer-mediated communication*" (*CMC*), which refers to human–human communication mediated by networked computers—especially the Internet—and other digital media. In that RMC mediates human–human communication and supports social as well as task-related interaction, it resembles textual modes of CMC such as email, text messaging, and (micro)blogging; graphical avatar-mediated communication in virtual worlds; and online audio and video chat. Unlike most CMC applications, however, RMC is asymmetrical, in that one person is telepresent via a robot (henceforth, the *pilot*) while others are physically present (henceforth, the *local* interlocutors).[3]

Not much research on RMC has been carried out by communication scholars to date.[4] One reason is that although telepresence robots have existed since the late 1990s (Paulos & Canny, 1998), high-definition video transmission and remote navigation use a great deal of wireless bandwidth,[5] and it has only become feasible to deploy such robots in real-world contexts since fiber optic technologies expanded Internet bandwidth in the mid-2000s. The first commercial telepresence robots were mobile robotic platforms designed for use by physicians in medical settings. In the past few years, the number of commercially available telepresence robots has grown,[6] and research and development are accelerating apace.

A consequence of this growth is that RMC is becoming increasingly prevalent and socially relevant. More people are using telepresence robots and producing RMC in an expanding range of contexts: business, educational, medical, and social. Telepresence robots are also used in security and high-risk operations such as surveillance, mining, and search and rescue, where it would be tedious or unsafe to send humans in; however, as communication is secondary in such uses (if it is relevant at all), they are not considered further here.

I research and use RMC in my professional academic life. The discussion that follows reflects my experiences piloting a variety of telepresence robots

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[3] It is possible for *all* parties to be telepresent through multiple robots, but unless the robots need to act in or on the physical space, it requires fewer resources and less effort for multiple remote interlocutors to interact in virtual space.

[4] An exception is the work of Leila Takayama (Lee & Takayama, 2011; Rae, Takayama, & Mutlu, 2013; Takayama & Go, 2012), who uses the term RMC in several of her publications.

[5] *Bandwidth* refers to the data throughput capacity of any communication channel (http://www.encyclopedia.com/topic/Bandwidth.aspx, retrieved December 11, 2015).

[6] Some of the more affordable ($2000–$3000) telepresence robots produced in the United States are the Double, the TeleMe, and the Beam+. More expensive models (ranging from $7000 to $70,000) include the VGo, the BeamPro, and the iRobot Ava. Recently, cheaper models produced overseas have entered the market, including the Chinese PadBot (listed at $950) and the Russian Synergy Swan (listed at $999). Prices are as of February 2016.

(in addition to several that I own) as well as the literature on telepresence robots and RMC. After briefly describing key technological properties of telepresence robots, I summarize what research has found regarding communication and social interaction through such robots, or what I call RMC broadly construed. Data-driven analysis of the actual, situated, and embodied communicative practices of interlocutors in telepresence robot-mediated conversations, or RMC narrowly construed, is largely lacking so far. Thus, I propose a framework with questions and methods to guide future study of telepresence robot-mediated discourse and language use. In the final section, I consider ways in which telepresence robots could be reconceptualized and redesigned, and raise questions about the intended and unintended consequences of RMC.

TECHNOLOGICAL PROPERTIES OF TELEPRESENCE ROBOTS

When people think of robots, they tend to think first of autonomous robots such as R2-D2 and C-3PO in the Star Wars movies. Autonomous robots depend on preprogrammed commands and artificial intelligence, and they are limited in their ability to communicate compared to human beings. In contrast, telepresence robotics is a form of robotic remote control by a human operator that is used to facilitate geographically distributed communication. Telepresence robot-mediated interaction is intended to simulate face-to-face (f2f) communication, and its success (or failure) is typically evaluated in comparison to f2f interaction. That said, the line between telepresence and autonomous robots often blurs, as when autonomous features, such as obstacle avoidance, are incorporated into human-piloted robots.

There are "child-sized" telepresence robots (such as the Telenoid, developed in Japan, which is intended to be held in the local user's arms) and smaller table-top devices (such as the Kubi and the MeBot). The focus of this essay is on "adult-sized" telepresence robots, which are the most widely deployed and the most studied to date. The following descriptions pertain especially to the adult-sized telepresence robots that are currently commercially available in the United States (referred to for convenience simply as "telepresence robots" or "robots" henceforth), as exemplified by the VGo, the QB, the BeamPro, the Beam+, the Double, and the iRobot Ava (Figure 1).

These devices are shaped and constrained by a specific set of technological properties:

Embodiment. A telepresence robot can be designed to look like a human being, but most versions in use today are not. The "head" of the typical telepresence robot is (or includes) a video monitor; some robots have

Figure 1 Some commercial telepresence robots.

an iPad or Android tablet as their video monitor. The head and shoulders of the pilot are typically visible in the video screen. The robot's "body," in contrast, is often little more than a vertical column mounted on a wheeled base, as shown in Figure 1. Robotic arms, because they are difficult to create and expensive to produce, usually are not included, although some designs include pointing devices.[7]

Size. Especially if the intended use is in a work environment, the general sense among designers is that the robot should be large enough to be taken seriously, but at the same time, not so large as to be perceived as intimidating or dangerous. That said, current commercial models range widely from 11 to 186 pounds, with heights from 2.8 to 6 feet, corresponding roughly to the height of a seated or a (short) standing adult human. Some robots allow the pilot to adjust the robot's height while in use.

Movement. The main movement of telepresence robots is rolling about in physical space. Similar to audio- and video-conferencing, most telepresence robots operate through a WiFi (wireless) network. The pilot remotely controls the movement of the robot through a computer interface that features various navigation controls and indicators; some robots can also be controlled via touch screen or a joystick. Today's robots typically have speeds equivalent to a (slow) walking pace. Some can automatically detect obstacles and edges (such as stairs) and prevent the robot from rolling into them. Some, such as the iRobot Ava, are equipped with automated point-to-point navigation. These automated features let the pilot focus less on navigation and more on communication.

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[7] The early PRoP robot, for example, included a two-degrees-of-freedom pointer "so that remote users [could] point as well as make simple motion[s]" (Paulos & Canny, 1998).

Audio and Video. The pilot "sees" through the robot's cameras and "hears" through its microphones, like in video conferencing. According to Neustaedter, Venolia, Procyk, and Hawkins (2016), the head camera on the BeamPro, a high-end telepresence robot, provides the equivalent of 20/200 vision. Peripheral vision is also typically limited, and in robots that use one head camera, depth perception is lacking. To partially compensate for these limitations, some head cameras include a zoom feature, and some pan and tilt. Some robots are also equipped with a camera that provides views down to the base to aid in navigation. As in videoconferencing, the pilot sees a small picture-in-picture image of him- or herself in the control interface; however, auditory feedback is often lacking.

Message Transmission. Telepresence robots support synchronous, ephemeral, two-way, voice-based communication, similar to audio–video conferencing and f2f communication. Some also let the pilot leave text on the robot's video screen, and my VGo converts text typed by the pilot into speech by the robot, which can be useful as a backup when audio transmission problems occur.

These properties have consequences for RMC, both broadly and narrowly construed.

COMMUNICATION AND SOCIAL INTERACTION THROUGH TELEPRESENCE ROBOTS

The primary aim of telepresence robots is to foster social interaction between individuals, or RMC broadly construed. That aim is often thwarted in practice, however, by network problems that result in unsynchronized audio and video streams or loss of network connectivity. The robot may bump into things or stall in the middle of a hallway, and audio or video may break up or be temporarily lost. Audio is more important than video in conveying a sense of presence; it is also essential for verbal interaction. I have found through experience that poor audio input quality in combination with limited vision can make locating and identifying the source of voices in the local environment challenging. Laggy audio can also compromise fundamental aspects of turn-taking and interruptions (O'Conaill, Whittaker, & Wilbur, 1993). As Desai *et al*. (2011) incisively conclude, "audio issues [can] make it difficult to have any conversation, let alone a natural conversation."

One must look beyond the present technical limitations of telepresence robots, however, to appreciate their communicative potential. When the technology works like it is supposed to, RMC has been found to be more casual and sociable than video conferencing. Telepresence robots that were used in technology workplaces for a year or more were found to enhance "impromptu work meetings" (especially to ask questions, exchange ideas, and get answers), "being available," "planned social meetings," "planned work meetings," "seeking people," and "greeting/socializing" (Lee & Takayama, 2011). Tsui *et al*. (2012) found that the novelty effect of using a telepresence robot wears off quickly, within 15 minutes. Sometimes, the robot becomes effectively "invisible-in-use" (Takayama & Go, 2012), such that the remote user and the local interlocutor(s) experience the subjective illusion of talking f2f.[8] Some pilots identify with the robots as themselves, to the point that they feel that their personal space is violated when a local user approaches too close or touches their robot. These findings lend support to Lee and Takayama (2011)'s claim that RMC blurs "boundaries … between person and machine, physical and virtual, and being here vs. being elsewhere."

At the same time, RMC can be socially awkward, and new norms of interaction must be negotiated as pilots and local interlocutors mutually adjust to the technological properties of telepresence robots. For example, local interlocutors are often unsure how to deal with a stalled robot, and may assume that the interaction has ended and walk away, rather than waiting a few moments for the pilot to reestablish a network connection or moving the robot into range of a WiFi hot spot. The robot may impede normal human traffic flow in a building or block others' view in meetings or at conferences without the pilot being aware of it, owing to the robot's limited range of vision. The pilot may misgauge social distance due to a lack of depth perception and position the robot too close or too far away from an interlocutor; may talk too loudly, owing to a lack of audio feedback; or may linger too long after a conversation, owing to missed social cues (Lee & Takayama, 2011). Unless they understand the robot's technological limitations, local interlocutors may interpret these behaviors as socially inappropriate or rude on the part of the pilot.

Locals may also ascribe social meaning to the robot's size. Robot height influenced local interlocutors' perceptions of leadership effectiveness in a study by Rae, Takayama, and Mutlu (2013), with robots that were taller than locals sitting down perceived as more leader-like than robots that were shorter than the seated locals.[9] Kristofferson *et al*. (2013) found that "people of different [height] preferred robots of different height and adjusted their distance to them accordingly." This may have stemmed from a desire to

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[8] Paradoxically, realistically humanoid (e.g., android-style) robots can distract and detract from the interaction experience (Mutlu, Yamaoka, Kanda, Ishiguro, Hagita, 2009), possibly because they only project the pilot's voice and movements, and not his or her face. Video is useful in "provid[ing] subtle information about the motions, actions, and changes at the remote location" (Paulos & Canny, 1998).

[9] Girth also matters, it seems. Leila Takayama (personal communication) reports that the thinner robots have less presence than the wider, more substantial ones.

look the pilot in the eye as much as possible, or to adjust for the perceived or desired power distance between the pilot and the local interlocutors.

The embodied nature of the robot is also relevant to issues of identifiability and anonymity. More than one person can pilot a robot (albeit not at the same time), and one person can pilot multiple robots. When more than one person uses the same robot or the same kind of robot, the anonymous appearance of the robot can make the pilot difficult to identify, especially from behind. Locals sometimes dress or decorate the robot, for example, with a hat, t-shirt, or scarf, to associate it with particular pilots (Neustaedter *et al.*, 2016). The robot's anonymous appearance may be advantageous, however, in circumstances where the remote participants wish to avoid drawing attention to themselves.

Ambiguity may also arise about a moving robot's intent, owing to gaze misalignment and a lack of gestural cues—does the pilot want to chat, or is he or she just trying to pass by? (Neustaedter *et al.*, 2016). As in video conferencing, the pilots' cameras are often facing in a different direction than their video image appears to be looking (Lee & Takayama, 2011), and thus the subtle cues that are normally exchanged via gaze f2f are not available in RMC. The pilot's gestures are also less visible. Some researchers have suggested that because facial expressions and nonverbal gestures are not as salient, telepresence-mediated interaction feels less "real" than f2f communication (Mantei *et al.*, 1991). My own experience piloting telepresence robots is that I am "present" at the remote location but not as present as if I were in my physical body. This too can have advantages: I have observed that locals' behavior tends to be more unguarded around my robot than it would be if I were physically present, and it is easier to observe others in social interactions when less focus is on me, as tends to occur once the novelty of the robot avatar wears off. Indeed, some pilots move the robot from side to side just to remind locals that they are there.[10]

Although lacking in the ability to produce human-like social cues, telepresence robots have other ways of signaling intention, such as flashing lights or gesturing with a laser pointer, and these can develop conventionalized meanings. The robot's mobility can be a form of body language for starting and stopping conversations; for example, slight movements may indicate the end of a conversation (Neustaedter *et al.*, 2016). Simply turning the robot's head or body to face the intended addressee is often an effective way to engage. In multiparty interactions, one study found that turning to look at a current speaker resulted in more and longer conversational turns. At the same time, "swiveling toward one [local] participant often meant that another [local] participant was left looking at the edge of the display screen" (Sirkin *et al.*,

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[10] Leila Takayama, personal communication.

2011), and the time required to rotate the display introduced delay into the conversation, disturbing its natural flow.

Related to movement, the robot's lack of arms means that it requires help to manipulate its surroundings (e.g., opening doors, pressing elevator buttons, moving objects), and this must be negotiated between pilot and locals. Because of this, some pilots report feeling like they are disabled (Lee & Takayama, 2011).[11] Locals may share this perception too. Takayama and Go (2012) found that people have different metaphors for telepresence robots, and their social expectations depend on those metaphors. Locals who view the robot as a machine, purely a mediating technology, tend to have lower social expectations of it; they are more likely to help the robot, while feeling less constrained by f2f norms of politeness. For instance, they might not consider it rude to put their feet up on the robot's base while conversing with it, or to mute the telepresence robot from the local side (Takayama & Go, 2012). In contrast, people who think of the robot as a person and a social actor tend to consider such behaviors impolite. Many subjects who thought of the robot as a person in Takayama and Go's study thought of it as a disabled person. The implications of the disability metaphor for politeness and helpful behavior have not been studied yet, however.

LANGUAGE AND DISCOURSE IN ROBOT-MEDIATED COMMUNICATION

"The most important component of communicating through a telepresence robot is the conversation itself" (Tsui *et al.*, 2012), or RMC narrowly construed. Yet although language and discourse in CMC has been described extensively,[12] almost no study has been made of the linguistic choices that interlocutors make in RMC—their patterns, their variations, their intended meanings, or their pragmatic effects. Moreover, no research has been based on close analysis of a corpus of actual RMC. Is language use more or less formal in RMC than in f2f? How do others refer to the robot—as "you," "s/he," or "it"—and what factors condition variation in reference? How does the limited mobility and range of visibility of pilots affect their ability to attract attention, gain and hold the conversational floor, and time turn-taking appropriately? What is the social and hierarchical status of the pilots: Are they taken less seriously when they are in positions of authority? Do they receive politeness and deference the same as if they were physically present, and to what extent does this vary by gender and culture—theirs and that of their local interlocutors?

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[11] In contrast, some physically disabled users, who otherwise might not be able to move about a remote site, experience robotic embodiment as empowering (Neustaedter *et al.*, 2016).

[12] For a recent overview, see Herring and Androutsopoulos (2015).

As a framework that could be used to guide exploration of these and related questions in the pilot's and the local interlocutors' discourse, I identify five categories of language use in RMC that could fruitfully be researched, organized from smallest to largest linguistic units and from least to most context dependent, with sample phenomena of potential interest listed for each category. Each category could be addressed by existing linguistic methods of analysis, modified to take into account the mediating properties of telepresence robots.[13] (*Italics* indicate phenomena that have been touched upon in the RMC literature.)

Structure. RMC- and context-specific conventions of language use; word frequencies; formality; organization of speaking turns, exchanges, and conversations; disfluencies; intonation and *volume*; gesture.

Meaning: Word Choice/Use. Discourse topics (What is the talk about?); interactive personal pronouns (e.g., "I", "we", "you") and *forms of reference* ("s/he", "it", "the robot", etc.); vocabulary diversity and size; *metaphor use*.

Meaning: Pragmatics. Speech acts (What are the speakers doing through language?); *determining intention*; observations and violations of conversational maxims; *politeness*; topic initiation, development, and termination; deixis; presupposition, implicature, and so on.

Interaction Management. *Attention-getting*; greeting; leave-taking (*termination of interaction*); preferred and dispreferred responses; *turn-taking*; back-channeling; pausing/silence/*inactivity* [verbal vs multimodal (cf. Licoppe & Morel, 2012)]; conversational repair; *gaze; orientation to current speaker*.

Social Phenomena. Stylistic differences according to gender, age, socioeconomic status, culture, role, experience with robots, and so on; *self-presentation* and self-revelation; lying and deception; playful behavior; giving and receiving support; *accommodation*; conflict and conflict management; *negotiation* (e.g., around use of shared space); power/*leadership*; influence; deference, and so on.

These categories are not discrete; a single phenomenon could be addressed on more than one linguistic level. Rather, the categories are intended as different lenses through which RMC can be viewed. Each lens brings into view different questions, methods, and theoretical perspectives.

Naturally occurring robot-mediated interactions constitute the most authentic data for studying language use in RMC. There are privacy issues

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[13] The organization of these categories follows that for computer-mediated discourse analysis, a paradigm developed for textual CMC (Herring, 2004).

associated with collecting such data, though, as it could be perceived as mobile surveillance. Moreover, unlike asynchronous web communication, RMC is not self-archiving; the researcher needs to devise methods of recording, transcription, and presentation for information not normally found in CMC, such as movement and gaze direction. Nonetheless, close analysis of language and discourse in RMC is an important and fruitful direction to pursue in future research.

Experimental methods are also valuable—for example, for comparing RMC, both narrowly and broadly construed, with other modes of communication. Such comparisons would spotlight different effects of robot mediation: RMC compared with f2f communication would shed light on the effects of the robot proxy; RMC versus video-mediated communication would illuminate the effects of ambulation; and RMC versus avatar-mediated communication would highlight the differential effects of physical and virtual environments, for instance.

Finally, surveys and interviews are useful for querying participants directly about RMC. In addition to their linguistic and social perceptions, local participants could be asked to what extent they felt that the pilot was present in a given interaction, toward the larger goal of understanding what circumstances contribute to creating the effect of “invisible-in-use” robotic telepresence.

THE FUTURE OF TELEPRESENCE ROBOTICS AND RMC

Referring to autonomous robots, Nourbakhsh (2013, p. xv) recently wrote, “[T]he ambitions of robotics are no longer limited to imitating [human beings]. … We have invented a new species, part material and part digital, that will eventually have superhuman qualities.” Similarly, telepresence robots need not be limited by “human” metaphors. Present iterations already have “superhuman” abilities, compared with what is possible in f2f communication: They enable a person to be in two (or more) places simultaneously, and they provide mobility across great distances to the mobility impaired. The first telepresence robot, Eric Paulos’s ProP, could also float through the air.

In theory, nearly any autonomous robot in use or development today could become a telepresence device with the addition of two-way audio–video communication. Communicating remotely with other people through “giant, military robo-dogs”[14] (Nourbakhsh, 2013) is neither necessary nor desirable, but the human-pilotable flying robots known as *drones* could make useful communication devices, in addition to being able to navigate

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[14] A reference to Boston Dynamics’ “Big Dog” military robot. See: http://www.bostondynamics.com/robot_bigdog.html.

outdoors over uneven terrain. Other nonhuman robotic designs suggest interesting possibilities for remote human interactions, as well, ranging from telepresence robots in the form of normal-sized dogs (to keep company with and comfort the ill and elderly) to robots with multiple, highly specialized arms (for remote surgical procedures).

To enhance robot-enabled multimodal, multicontinental telepresence, future robots could include built-in navigation and map-creation technology; automated speech translation across languages; augmented reality technology that overlays the video with information about current or anticipated interlocutors drawn from an Internet database; and sensors to collect information about the remote environment, ranging from proxemic information about when a person is trying to squeeze by to information about interlocutors' emotional states. The robots could change appearance according to who is piloting them at the moment. For example, they could include screens upon which holographic images are projected, so that a moving, speaking, three-dimensional representation of the pilot's physical self is visible in the remote environment. Making the remote pilot's identity readily visible is one way to encourage more human–human interactions, and making the remote pilot visible from all angles would make bystanders more likely to enter into conversations (Takayama & Go, 2012). Pilots, at their end, could wear virtual reality gear to simulate an experience of immersion in the remote environment, and their body motions could be tracked and mirrored in the remote robot. The robots themselves could be flexible, pliable, and gentle to the touch.

Meanwhile, the telepresence literature is filled with recommendations for ways to improve the current paradigm of "videoconferencing on wheels." More and better cameras would provide the pilots with better situation awareness (Desai *et al.*, 2011). Convex video displays could afford a wider range of directing a pilot's gaze while not "turning her back" on some participants (Sirkin *et al.*, 2011). Some current video conferencing systems use audio location to work out who is speaking and then focus cameras on that speaker (Yoshimi & Pingali, 2002); this could also be done for robots. A screen with a camera embedded in the middle would aid interlocutors in establishing eye contact (Kristoffersson *et al.*, 2013). Features to provide remote pilots with more feedback about how they are presenting themselves—for example, providing mechanisms to help monitor their volume levels, monitor their appearance, and communicate nonverbally—could improve the user experience for both remote pilots and locals (Lee & Takayama, 2011).

The robot's base could have treads that would allow it to roll over curbs and climb stairs (Paulos & Canny, 1998). Lasers could assist navigation when passing through doorways and while driving down hallways; for example, if the robot drives at an angle toward a wall, the robot could autonomously correct its direction (Desai *et al*., 2011). Autonomous navigation is desirable in general for safety reasons, for ease of use, and to reduce social awkwardness associated with bumping into walls and other objects. In studies by Desai *et al*. (2011), a "follow person" behavior and a "go to destination" mode were rated as potentially quite useful. However, automation raises issues of ethics and legal liability. As Takayama and Go (2012) ask, "If a semi-autonomously navigating MRP (mobile remote presence) system bumps into a person or damages valuable furniture, who is to blame?" Adjustable autonomy would allow the pilot to select from a range of autonomous behaviors or levels according to circumstances.

At present, the main bottlenecks to the widespread adoption of telepresence robots are Internet/WiFi reliability and the cost of acquiring units. Costs are already dropping as new models appear on the market.[15] As for lost WiFi connection due to limitations in range of WiFi and "network shadow" caused by metal objects such as elevators and lockers, Kristoffersson *et al*. (2013) propose automatically "reversing the [robot's] motion in slow speed until sufficient access to the WiFi is recovered." They also suggest adding a light or backup beep "to indicate the robot's intention."

Some suggestions from the research literature have already been implemented in robotic prototypes. Articulating arms, for instance, have been implemented on the MeBot V4 tabletop telepresence robot. The robot has two arms with three degrees of freedom: shoulder rotation, shoulder extension, and elbow extension; the arm movements are directly controlled by the pilot, who adjusts the joints on a passive model of the robot (Kristoffersson *et al*., 2013). The researchers who designed the MeBot V4 found that local users rated it as more engaging and likable than a similar static robot design. The success of this prototype raises the possibility that a similar approach could be adapted to adult-sized robots, although body tracking would be more direct. However they are implemented, remotely controllable arms would greatly increase the ability of telepresence robots to interact with and in remote environments, rendering them both more sociable (e.g., able to gesture, shake hands, and hug) and less "disabled" and dependent on assistance from local interlocutors (e.g., to press elevator buttons and open doors).

As Nourbakhsh rightly observes, robot proxies expand our physical space and reach. At present, the implications of that expansion have only begun to be felt, implications that extend beyond the fields of technology design, human–robot interaction, and CMC into the social and behavioral sciences, and from there into any number of applied domains. Rae, Venolia, Tang,

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[15] See note 6.

and Molnar (2015) caution that designers and researchers should keep in mind what future they are trying to invent with telepresence. Because the focus of this essay is on communication, I have not considered other ways in which telepresence extends human experience that do not primarily involve human–human communication, including actions that would be impossible in one's physical body such as extreme mountain climbing, or perceiving/feeling through the eyes/body of another person wearing a telerobotic skin. Such applications of telerobotics raise fascinating questions in their own right.

As regards RMC, researchers need to consider the nature of the communication that telepresence robots are used to support, between what kinds of communicators, for what purposes, and in what contexts? Beyond these primary, or intended uses, what secondary or unintended consequences might follow from RMC? The popular media are filled with hype and warnings about our future coexistence with robots. Telepresence robots are human proxies, not autonomous machines; nonetheless, their impact if they come into widespread use could be as great as that of autonomous robots. This is all the more true as the line between autonomous and teleoperated robots continues to blur.

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