Social Cognition, Vol. 26, No. 2, 2008, pp. 169-181

ANTHROPOMORPHIC INTERACTIONS WITH A ROBOT AND ROBOT–LIKE AGENT

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People's physical embodiment and presence increase their salience and importance. We predicted people would anthropomorphize an embodied humanoid robot more than a robot–like agent, and a collocated more than a remote robot. A robot or robot–like agent interviewed participants about their health. Participants were either present with the robot/agent, or interacted remotely with the robot/agent projected life–size on a screen. Participants were more engaged, disclosed less undesirable behavior, and forgot more with the robot versus the agent. They ate less and anthropomorphized most with the collocated robot. Participants interacted socially and attempted conversational grounding with the robot/agent though aware it was a machine. Basic questions remain about how people resolve the ambiguity of interacting with a humanlike nonhuman.

By virtue of our shared global fate and similar DNA, we humans increasingly appreciate our similarity to nature's living things. At the same time, we want machines, animals, and plants to meet our needs. Both impulses perhaps motivate the increasing development of humanlike robots and software agents. In this article, we examine social context moderation of anthropometric interactions between people and humanlike machines. We studied whether an embodied humanlike robot would elicit stronger anthropomorphic interactions than would a software agent, and whether physical presence moderated this effect.

At the outset, robots and agents differ from ordinary computer programs in that they have autonomy, interact with the environment, and initiate tasks (Franklin & Graesser, 1996). The marriage of artificial intelligence and computer science has made possible robots and agents with humanlike capabilities, such as lifelike gestures and speech. Typically, "robot" refers to a physically–embodied system whereas "agent" refers to a software system. Examples of humanlike robots are NASA's Robonaut—a humanoid that can hand tools to an astronaut (robonaut.jsc.nasa.gov/robonaut.html), Honda's Asimo, and Hiroshi Ishiguro's

This research was supported by National Science Foundation grants IIS–0121426 and HSD–0624275.

We thank Hau–Yu Wong, Sean Gilroy, Greg Armstrong, Judy Matthews, and the People and Robots, Nursebot, and Social Robots project teams for their suggestions and help.

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android, Gemini. Software agents include animated icons like Clippit, the Microsoft Office 97 software assistant, voice conversational help bots on websites, and three–dimensional characters and avatars in online virtual worlds.

Anyone who has tried to make an airline reservation with "Alan," the automated telephone system, knows we have far to go before machines interact smoothly and naturally with people. Yet robots and agents have begun to give researchers a unique window on human social cognition (Scassellati, 2004). People stereotype software agents based on their humanlike faces (Yee, Bailenson, & Rickertsen, 2007) or voice (Nass & Brave, 2005), and they think baby–face robots are sociable (Powers & Kiesler, 2006). Participants assume a robot has different knowledge of landmarks depending on its purported nationality (Lee, Kiesler, Lau, & Chiu, 2005) and different knowledge of dating depending on whether its voice is male or female (Powers et al., 2005).

People also project their attitudes onto machines, and they respond positively to similarity in features or behaviors that, in people, encourage projection (Ames, 2004). A human face on a software agent induces participants to cooperate with the agent as much as they do with a real person (Parise, Kiesler, Sproull, & Waters, 1999). Participants recognize extroverted and introverted synthetic speech on a book buying website and reveal similarity–attraction responses in their book reviews and reviewer ratings (Nass & Lee, 2001). Mimicry in an agent (Bailenson & Yee, 2005) and perspective taking in a robot (Torrey, Powers, Marge, Fussell, & Kiesler, 2006) lead to more favorable attitudes.

The cognitive process of anthropomorphism may involve some variant of instance–based (e.g., Hintzman, 1986) or exemplar–based processing (e.g., Linville, Fischer, & Salovey, 1989) and analogistic mapping (Gentner & Markman, 1997). Viewing a humanlike machine may activate associations created from experience with people, machines, and population stereotypes of fantasy characters. For example, a lifelike robot that tells a joke might activate exemplars of the nonsocial category, *machines*, and of the social category, *humorous people*. Combining these exemplars could lead to the experience of an integrated concept, such as *cheerful robot*.

A machine that engages with the environment is likely to enervate this process (e.g., Scholl & Tremoulet, 2000; Rakison & Poulin–Dubois, 2001). In Heider and Simmel's (1944) film (http://anthropomorphism.org/psychology2.html), participants perceived a meaningful structure in the movement of three animated objects, and created elaborate social narratives to describe them (see also Berry, Misovich, Kean, & Baron, 1992). Running the Heider–Simmel film backwards, or changing its speed, destroys its perceived meaningfulness, implying dependence on precise psychophysical events.

Nonetheless, perceptual events do not explain all social aspects of anthropomorphism. In one study, participants who owned a dog were more cooperative with a doglike software agent than those who did not own a dog (Parise et al., 1999). In another study, when participants were asked to imagine "their own dog" or "a neighbor's dog" enacting the identical behavior, they explained their imagined own dogs' behavior more anthropomorphically; this difference held even among those who did not actually own a dog (Experiment 1, Kiesler, Lee, & Kramer, 2006). This result mirrors people's tendencies to attribute more complex human qualities to people they like (Leyens et al., 2000). If our relationship with an animal or object changes how we anthropomorphize it (Kiesler, Lee, & Kramer, 2006), then a context–sensitive process of anthropomorphizing machines and animals would seem to exist, running in parallel to perceptual processes. Perhaps such a process evolved as humans learned to protect and value other people and animals (Caporael & Heyes, 1997).

If anthropomorphism is partly a value prescription process that facilitates potential interaction, then face–to–face interaction with a humanlike machine should prompt greater anthropomorphism of the machine. Two important attributes of face–to–face interaction are that one's partner is embodied and that he or she is physically present. The actual presence of others is physiologically arousing, causing "social facilitation" (Zajonc, 1965). Embodiment and presence could make a machine salient and important, encouraging anthropomorphism.

Embodiment is not the same as presence. We are more engaged with real, embodied people than those who are projected even if they are not actually interacting with us (e.g., Schmitt, Gilovich, Goore, & Joseph, 1986). The human brain processes embodied structures differently than those that appear in two dimensions (e.g., Kawamichi, Kikuchi, & Ueno, 2005). We think this distinction is true of technology as well. Software agents on a screen a few inches away can move in lifelike ways that today's robots cannot—swim, fly, and run. On the other hand, a robot is three–dimensional, moves in 3–D space, and can manipulate objects or even touch us. In accomplishing such actions, robots must obey gravity and the limitations of their electro–mechanical systems. Just one study evaluated the impact of embodiment in machines. Yamato Shinozawa, Naya, & Kogure (2001) compared a small robotic rabbit with an agent that looked like the same robot, presented on a computer monitor. Both were about three feet from the participant. The authors reported that participants felt closer to the robot but were more influenced by the agent's choice on a simple color selection task. The authors did not measure anthropomorphism, however.

Another characteristic of face–to–face interaction that can make interactions salient and important is that one's partner is physically collocated. This proximity causes people to structure their representations concretely (Henderson, Fujita, Trope, & Liberman, 2006) and increases people's concern with being evaluated, or "evaluation apprehension" (Guerin, 1986). Evaluation apprehension may be responsible for conformity to others in their presence, choking effects, and reduced disclosure of sensitive information in the presence of others.

For the reasons described above, we hypothesized:

- H1. Participants will anthropomorphize a robot more than a robot–like software agent. They will find it more lifelike, more engaging, and more likeable. They will be more influenced by the robot than the agent, but will disclose less personal information to the robot.
- H2. Participants will anthropomorphize a collocated robot more than a remote robot projected on a large screen before them. They will find the collocated robot more humanlike, more engaging and likeable, be more influenced by it, but will disclose less personal information to it.

We also measured participants' memory for the agent's or robot's dialogue but did not make a prediction. People may process face–to–face conversation more deeply than remote conversation but their involvement in conversational grounding and self–presentation might interfere with remembering the material discussed.

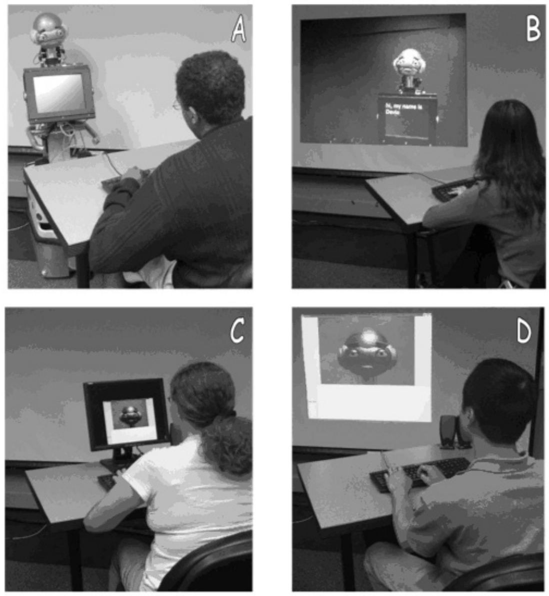

FIGURE 1. Four conditions of the experiment. A = Robot present with participant, B = Robot remote and projected to the participant, C = Software agent present with participant, D = Software agent remote and projected to the participant

METHOD

The design was a between–groups design (Robot vs. Agent × Present vs. Projected). In the robot conditions, the participant was either collocated with the robot (Figure 1A) or in a different room and saw the robot projected in real time onto a large screen (Figure 1B). In the agent conditions, the participant was either collocated with a computer monitor on which the agent was displayed (Figure 1C) or in a different room from the monitor and saw the agent projected live onto a large screen (Figure 1D).

PARTICIPANTS

We recruited 113 participants from the community in and near Carnegie Mellon University. They were paid $10. Participants were 52% male, with an average age of 26 years (range 17–57). The participants represented 56 fields of study or work, including architecture, film and theatre, business, medicine, and journalism. Only 10 participants specialized in computer science or robotics. Because of our attempt to add an additional factor, we assigned twice as many participants to each robot condition (remote robot $n = 38$, collocated robot $n = 37$) than to each agent condition (*ns* = 19). In half of each robot condition, the robot moved autonomously from the doorway to the participant at the beginning of the experiment. This manipulation did not have any effect on the results, and we have collapsed across these conditions.

PROCEDURE

The experimenter told participants that their goal was to "have a discussion with this robot about basic health habits." So that different instructions did not influence outcomes, the experimenter referred to the interviewer as a "robot" in every condition. The robot or robot–like agent spoke aloud to the participants and participants replied by typing on a keyboard (see below). The robot or agent asked the participants about their exercise, diet, weight and height, mental well being, and teeth flossing, and encouraged them to engage in healthy behaviors such as eating less fat and more salads, and exercising more. The robot or agent also asked five sensitive questions from the Crowne and Marlowe (1960) social desirability scales, such as "Have you ever deliberately said something against someone?" The robot or agent also told several jokes. (e.g., "Do you know, why did the lettuce go red?" "Because it saw the salad dressing.") The dialogue took 10–15 minutes. At the end of the session, the experimenter reentered the room, asked participants to complete an online questionnaire, and offered them a bowl of snack bars.

EQUIPMENT

The robot Nursebot was used in the robot conditions. Nursebot has an animated face with 17 degrees of freedom, including eyebrows, eyelids, eyes, mouth, and neck. It stands 53 inches tall, with a head about 8 inches wide and 7 inches high. In the present condition, the robot stood 44 inches away from the subject. In the remote projected condition, the robot was in another room; an image of the robot was projected onto a large screen 50 inches away from the participant, to control for the robot's apparent size. The software agent's appearance was created from a photo of the robot's head and neck. In the present condition, the head was displayed 4.5 inches wide and 3.5 inches tall on an LCD screen, 21 inches away from the participant. In the remote projected condition, the agent's head, 16 inches tall and 13 inches wide, was projected on the large screen, 50 inches away from the participant.

The robot's facial motions were scripted to match the content of the dialogue. In the present and projected robot conditions, the lips were synched with a male voice, using Theta (Lenzo & Black, 2007). As expected, participants rated the robot/agent as more masculine than feminine (F [1, 109] = 4.9, $p < .05$). Like the robot, the agent moved its lips in synchrony with its male–voice speech. However, the agent was not as physically expressive as the robot, in that it could not turn its body, or move its head, eyes, or eyebrows.

The robot and agent spoke all of their lines aloud. The second author built a dialogue engine that branched and could ask for more elaboration of vague responses. The participants typed all of their responses on an interface similar to instant messaging. Their typed input appeared on a monitor on the robot (Present Robot condition) or below the agent or robot on the monitor or the projected image. We did not use speech recognition because this technology is still too primitive; we wanted to allow participants to converse as fully as possible. We kept a record of all conversations.

TABLE 1. Measures in the Experiment.

Type of Measure	Measure	Scale or Observation
Manipulation check	Self–report: Sense of presence	Felt presence, real discussion, same place (3 items, α = .74)
Engagement	Time with robot	Minutes in conversation (log)
Disclosure	Disclosure of sensitive information	Did the participant admit negative behavior?
		How much did the participant disclose about himself/herself in response to disclosure questions? (Log word count)
Social influence	Eating	Did the participant eat health bars rather than candy bars?
		Did the participant eat fewer calories?
	Self–report: Intentions	Did the participant agree to read for pleasure, eat salads, exercise (how often), and floss his/her teeth next week?
Conversational memory	Memory of information from robot	Number of information facts recalled out of 8 possible.
Attributions	Self–report: Lifelikeness	Humanlike, lifelike, machinelike (rev.), natural
		(1– 7 scale, 4 items, α = .83)
	Self–report: Traits	Dominant
		(1– 7 scale, 4 items, α = .83)
		Trustworthy
		(1– 7 scale, 5 items, α = .83)
		Sociable
		(1– 7 scale, 10 items, α = .89)
		Responsive
		(1– 7 scale, 6 items, α = .88)
		Competent
		(1– 7 scale, 14 items, α = .93)
		Respectful
		(1– 7 scale, 3 items, α = .76)
Other	Self–report: Task enjoyment	Conversation helpfulness
		(1– 7 scale, 9 items, α = .91)
		Good content
		(1– 7 scale, 3 items, α = .69)
		Enjoyment of task
		(1– 7 scale, 7 items, α = .87)
	Self–report: Mood	Affect
		(1– 7 scale, 4 items, α = .83)
	Self report: Effort	NASA workload
		(1– 7 scale, 3 items, α = .65)

DEPENDENT VARIABLES

The measures are described in Table 1. The behavioral measures included engagement (interview time), disclosure, social influence, and conversational memory. We also administered a posttest questionnaire to obtain self–reports of participants' subjective experience and attributions of the robot or agent. The manipulation check of the embodiment manipulation (robot vs. agent) was to count the number of participants who said that the robot was not "real." To check on the manipulation of presence we measured participants' rated sense of presence.

RESULTS

Tests of the hypotheses were conducted using analysis of variance to examine the difference between the robot and agent condition, and a planned contrast of the robot conditions to test the difference between the present robot and the projected robot.

PRELIMINARY ANALYSES

Several participants were not fluent English speakers and had trouble understanding machine–generated speech. The questionnaire item, "I was able to understand what the robot was saying," predicted incomplete or "I don't understand you" responses during the interview with the robot or agent. We used scores on the speech comprehension item as a covariate in the analyses. In some analyses reported below, there are fewer than 113 scores due to machine malfunction or participants' not responding to a questionnaire item. We transformed skewed variables (time, word counts, calories) using a log transformation.

Of the 38 participants in the agent conditions, 12 complained that the agent was not a "real robot" (e.g., "I was expecting an actual robot—a physical being."). No participants complained in the robot conditions that the robot was not real. Participants in the present conditions felt a greater sense of presence with the present robot or agent than in the projected conditions (F [1, 108] = 3.8, p = .05). Participants also felt a greater sense of presence with the robot versus the agent (F [1, 108] = 4.3, p < .05) suggesting that embodiment and presence are not entirely independent factors.

ENGAGEMENT

We predicted the robot would be more engaging than the agent, and the present robot more engaging than the projected robot, as measured by the amount of time that the participant spent with the robot or agent. The main effect for robot versus agent was significant, M = 13.8 minutes (SE = .21) versus M = 12.9 minutes (SE = .29); (F [1, 105] = 6.5, p = .01). The presence main effect and interaction term were not significant, and neither planned contrast was significant.

DISCLOSURE

The agent or robot asked the participants five sensitive questions. We hypothesized participants would disclose less about themselves to the robot than to the agent, particularly when the robot was present. Those in the robot condition tended to admit fewer indiscretions (F [1, 108] = 2.9, p = .09). We also counted the number of words that the participants used to describe their socially undesirable behavior (e.g., "I told my sister I hated her") and compared that number with the number of words that participants used in the rest of the interview. Of those who elaborated their disclosures, those who interacted with the robot disclosed comparatively less than participants who interacted with the agent (interaction F [1, 115] = 4.2, p < .05). Responses to the present and projected robots did not differ.

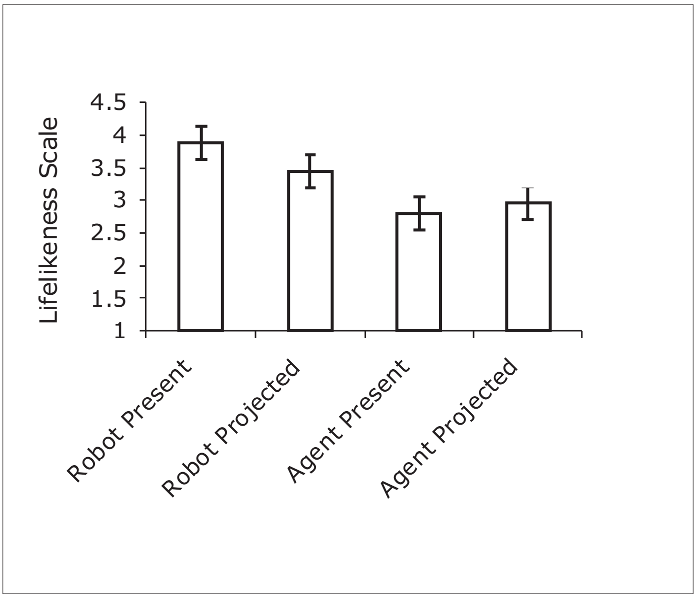

FIGURE 2. Ratings of the robot's and robot-like agent's lifelikeness

INFLUENCE

Nearly all participants said they intended to exercise and eat less fat in the future, and the robot or agent did not influence these responses. However, participants' responses to the offer of snack bars did differ by condition. When participants were present with the agent or robot, they were more likely to choose a health bar than a candy bar (interaction (F [1, 108] = 3.3, p = .07) and those who chose a snack bar and interacted with the collocated robot ate fewer calories (interaction F [1, 70] = 3.1, p = .08; Present robot vs. Projected robot contrast F = 6.4, p = .01).

CONVERSATIONAL MEMORY

The questionnaire contained 8 memory questions. Those in the robot condition remembered fewer items correctly (M = 4.9, SE = .18) than did those in the agent condition (M = 5.6, SE = .25; F [1, 107] = 5.7, p = .01). The robot might have been more distracting than the agent due to the participant's greater effort at self–presentation or conversational grounding.

ATTRIBUTIONS

Participants rated the robot as more lifelike than the agent (F [1, 108] = 10, $p < .01$). These ratings are shown in figure 2. The interaction with presence was not significant (F = 1.4).

A within–subjects analysis across the trait scales showed that participants rated the robot as having a stronger and more positive personality than the agent (F [1, 108] = 10.2, $p < .01$). The ratings shown in figure 3 show that the robot was viewed as more dominant, trustworthy, sociable, responsive, competent, and respectful. The interaction with presence was not significant ($F = .5$) but, as predicted, the contrast of present robot versus projected robot was significant ($F = 5.1$, $p < .05$).

OTHER MEASURES

Ratings of how much participants enjoyed the task were not different across conditions (overall mean = 5.8 on the 7 point scale). Ratings of the helpfulness of the robot showed a marginal preference for the robot's contribution over the agent's ($M = 5.1$, $SE = .2$ vs. $M = 4.5$ $SE = .25$; F [1, 112] = 3.6, $p = .06$). Also, ratings of the information content in the interview showed a trend to prefer the robot's content (even though it was identical to the agent's; $p = .1$), and there was a significant main effect of presence, present mean = 4.8, $SE = .17$ vs. projected mean = 4.2, $SE = .17$ (F [1, 112] = 6.5, $p = .01$).

DISCUSSION

We predicted a robot would be more engaging than an agent. Our results indicate that interacting with the embodied robot was a more compelling experience for participants and elicited more anthropomorphic interaction and attributions. Participants spent more time with the robot, liked it better, attributed to its stronger, more positive personality traits, and said it was more lifelike. Consistent with previous research on face–to–face interaction, participants were more inhibited with the robot than with the agent; they disclosed less socially undesirable behavior to it and consumed fewer calories after interacting with it. In short, these differences suggest that the participants interacted with the robot more as a person than they did with the agent. We also hypothesized that participants would find a collocated robot more compelling than a remote robot projected lifesize on a screen. Although some trends in this direction were evident (see, for example, trends in Figure 3), most of these comparisons were not statistically significant. Two unusual aspects of the environment probably contributed to the weakness of the presence variable. First, participants experienced the robot as more present than the agent; this finding replicates previous research suggesting that embodiment may be confounded with sense of presence (Nowak & Biocca, 2003). Second, the robot in the remote condition was projected life–size in high resolution on a large screen. This high fidelity might have reduced the robot's apparent remoteness.

This experiment tested only one instantiation of a robot and agent. We had only one autonomous robot, and the agent was modeled on the likeness of the robot to control for differences in appearance across conditions. Even small differences in the shape of the robot's head can affect participants' perceptions of a robot (Powers & Kiesler, 2006). Had we chosen a different robot–agent pair to study, for example, a robot versus a 3–D agent in an immersive virtual environment, the results might be different.

Because of the comparative weakness of the presence variable, this experiment does not settle a question we posed earlier, as to whether anthropomorphism is an automatic "bottom up" feature matching process or whether it is modified by social context as suggested by previous research (e.g., Kiesler et al., 2006). Anthropomor-

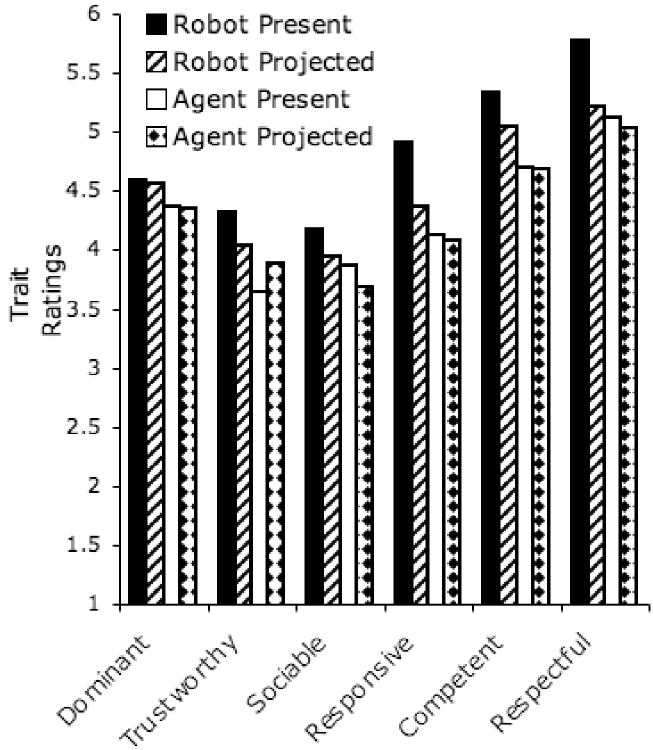

FIGURE 3. Trait ratings of the robot and robot-like agent

phic responses to the robot as compared with the agent might have been elicited by the robot's greater expressiveness, which in turn could have facilitated the participant's relationship with the machine (Berry, Butler, & Rosis, 2005).

UNDERSTANDING ANTHROPOMORPHISM

Previous research and everyday experience suggest that even when people's abstract understanding of an entity is clearly not anthropomorphic, their social behavior and attributions may be anthropomorphic (Barrett & Keil, 1996). In this experiment, participants knew they were conversing with a machine but their conversations were surprisingly true to social scripts of the sort one would expect in an experiment with a human confederate. Although we asked participants to answer the robot's health questions, we did not require that they converse socially with it. However, social conversation was the rule for participants. When the robot/agent said "hello," all participants replied with a hello or more informally ("hi," "hi there," or "hey"), and many participants volunteered how they were feeling, "I missed lunch," "I didn't sleep too well last night"). Those in the robot condition were slightly more informal (57% versus 49% in the agent condition), assessed by counting slang (e.g., "hi" versus "hello").

When the robot or agent told a joke, many participants laughed aloud and almost all typed a response, "he he," or "ha ha." When the robot or agent complained about its difficulty in exercising, participants answered politely, with sympathy ("that's too bad," " I'm sorry to hear that," "me too"), or with advice ("robots don't need to exercise," "you're not missing much"). When the robot bemoaned its weight, participants made light of it ("you look pretty trim") or commiserated ("I worry about my weight too"). Just twelve participants mentioned technology ("technology is improving," "yes, batteries weigh a lot"). One comment illustrates how participants integrated machine concepts with anthropomorphic interaction, "Yeah, I hate carrying heavy laptop batteries around!" In another memorable session, a servo in the robot's head broke and began burning during the experiment, causing a thin trail of smoke to rise out of the robot's head. Instead of retrieving the experimenter, the participant typed to the robot, "Your head is smoking."

The robot/agent could not be interrupted and sometimes did not have the participant's responses in its database, so it was fairly ineffective at conversational grounding. Participants showed some understanding of this inadequacy, but nonetheless attempted repair to achieve shared meaning. For example, in the context of talking about eating salads, the robot/agent asked participants if they had heard a joke about lettuce. A participant knew the joke ("I've heard that before") and gave the punch line but the robot gave it anyway. The participant then repeated twice, "I knew that one." After the experiment, the most common complaint about the experiment, other than that the voice should be more intelligible, was that the robot needed to be more flexible and interruptible (". . . if it could do that, that would be awesome").

Previous work and the informal observations noted above suggest that people may hold parallel but different understandings of a machine (and by extension, any nonhuman)—a level that consists of nonanthropomorphic abstract knowledge or beliefs about the entity, and a more concrete, socially–engaged level consisting of anthropomorphic meanings and behaviors. Since Francis Bacon, the latter phenomenon has been derogated, characterized as "folk psychology," and was the target of science education (see Guthrie, 1993; Mitchell, 1997). A counter–movement has pointed to the biological similarity we hold with animals (Crist, 1999) and the functional usefulness of anthropomorphic thinking (Panksepp, 2003). We speculate that a debate about whether anthropomorphic meaning is educable or not, fallacy or truth, is likely to continue even as we discover its basis in human social cognition.

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