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Brief article

Can we talk to robots? Ten-month-old infants expected interactive humanoid robots to be talked to by persons

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Abstract

As technology advances, many human-like robots are being developed. Although these humanoid robots should be classified as objects, they share many properties with human beings. This raises the question of how infants classify them. Based on the looking-time paradigm used by [Legerstee, M., Barna, J., & DiAdamo, C., (2000). Precursors to the development of intention at 6 months: understanding people and their actions. *Developmental Psychology*, *36*, 5, 627–634.], we investigated whether 10-month-old infants expected people to talk to a humanoid robot. In a familiarization period, each infant observed an actor and an interactive robot behaving like a human, a non-interactive robot remaining stationary, and a non-interactive robot behaving like a human. In subsequent test trials, the infants were shown another actor talking to the robot and to the actor. We found that infants who had previously observed the interactive robot showed no difference in looking-time between the two types of test events. Infants in the other conditions, however, looked longer at the test event where the second experimenter talked to the robot rather than where the second experimenter talked to the person. These results suggest that infants interpret the interactive robot as a communicative agent and the non-interactive robot as an object. Our findings imply that infants categorize interactive humanoid robots as a kind of human being.

Keywords: Communicative agent; Human–robot interaction; Humanoid robot

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1. Introduction

Many robots that have appeared in science-fiction movies (such as "R2-D2"[1] in *Star Wars*) are mechanical in appearance, but make many communicative actions, such as uttering beeping-sounds, moving their heads, and/or blinking a light. Almost everyone who watches R2-D2 will be convinced that the robot has something like a mind.

As technology advances, it is no longer fantasy or fiction that human beings can live with robots. "AIBO",[2] a dog-like robot, is enjoyed by many ordinary Japanese families. More humanlike robots such as "ASIMO"[3](Sakagami, 2002), "QRIO",[4] and "Robovie" (Ishiguro et al., 2001) are also being developed for household use. Although these robots do not exactly resemble human beings, they have equivalent body parts such as a head, a face, hands, arms, a trunk, and so on. Technology also allows us to interact with robots via a variety of gestures and voices. Robovie, for example, can make hand gestures and eye contact, and also speaks natural languages. The robot can behave like a human being and communicate verbally and non-verbally. This opens the question of how infants categorize such robots.

Developmental psychology has addressed the issue of how infants characterize humans as agents having mental states. Some studies suggest that infants attribute mental states only to humans (Field, Woodson, & Greenberg, 1982; Legerstee, 1991; Meltzoff, 1995). For instance, using infants' looking time as a measurement of violation-of-expectation, Legerstee et al. (2000) found that infants do not expect people to talk to objects. In their experiment, infants were shown an actor who talked to something hidden behind a curtain. When the curtain was opened, an object such as a broom or a person appeared. The infants looked longer when the object appeared than they did when the person appeared. These results suggested that infants do not expect non-human objects to be talked to, and that infants think that only humans can communicate with humans. In the context of this research, it is understandable that infants did not perceive objects as agents, because these studies used ordinary objects like wooden rods, machine arms, dolls, and a radio-controlled toy having few human-like features and motions (Legerstee, 1994, 1997, 2001; Meltzoff, 1995; Poulin-Dubois, Lepage, & Ferland, 1996; Woodward, 1998). Other studies have suggested, however, that infants attribute mental states to non-human objects that appear to be interactive with a person: a box-shaped machine that beeped and flashed light, or a small fur ball that making noises and flashed lights (Movellan et al., 1987; Johnson, Slaughter, & Carey, 1999; Johnson, Booth, & O'Hearn, 2001). These results imply that *interactivity* between humans and objects is the key factor in mental attribution, however, interesting questions remain to be answered: do infants characterize *humanoid robots* that behave like humans as mentalistic agents? Or, do infants also attribute mental states to *humanlike* but *non-interactive* robots?

In this study, we used an experimental paradigm similar to Legerstee et al. (2000) to investigate whether 10-month-old infants expected an experimenter to talk to

[1] http://www.starwars.com/databank/droid/r2d2/index.html
[2] http://www.us.aibo.com/
[3] http://asimo.honda.com/
[4] http://www.sony.net/SonyInfo/QRIO/top_nf.html

the humanoid robot "Robovie". To show infants how the robot behaved and interacted with people, we added a familiarization period prior to the test trials in which another actor talked to the robot and the person.

There were three experimental conditions. The stimuli in the familiarization of these conditions are as follows:

(1) Interactive robot condition: the robot behaved like a human, and the person and the robot interacted with each other.
(2) Non-active robot condition: the robot was stationary and the person was both active and talked to the robot.
(3) Active robot condition: the robot behaved like a human, and the person was stationary and silent.

In the latter two conditions, there were no two-way human–robot interactions. During the test trials, infants saw a person speak to the robot and the other person. If infants regard only interactive robots as communicative agents, they will not be surprised only in the interactive robot condition, implying that interactivity is crucial for infants' attribution of social mental states to objects. But if infants regard humanlike robots as communicative agents only because they behave like humans, they will not be surprised in either the interactive robot or active robot conditions.

2. Method

2.1. Participants

Fifty-eight 10-month-old infants ($M = 10.15$ months of age, $SD = 0.51$) were randomly assigned to one of the three experimental groups or to the control group in a between-subjects design. Ten infants were excluded from the study: two because of experimenter error, two because of sleepiness, and six because of fussiness. The remaining 48 infants (36 in the experimental groups [19 males, 17 females] and 12 in the control group [eight males, four females]) were healthy, full-term babies.

2.2. Stimuli

Infants viewed recorded interactions of human actors with "Robovie," a robot that has a humanlike appearance and is designed to communicate with humans (Fig. 1). The robot, 120 cm tall and 40 kg, was equipped with sensors to mimic vision, touch, and hearing. With these sensors and its humanlike body, the robot produced meaningful interactive behaviors (behaviors and speech were programmed by the researchers) with humans. The human actors who interacted with the robot were naïve to the purpose of the experiment. Interactions were recorded by a DVD-HDD recorder (Toshiba: RD-2000), and the videos were displayed on a TV monitor (Sony: KW-28HDF7).

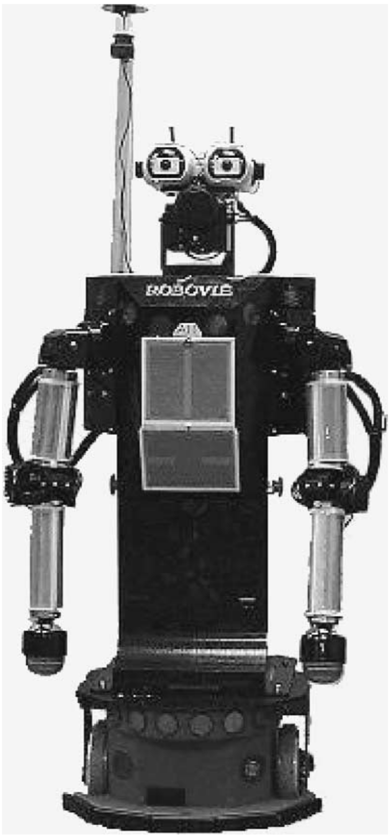

Fig. 1. The humanoid robot “Robovie” used in the study.

2.3. Procedure

The experiments were conducted in a university laboratory assessment room. Each infant was seated in the lap of his or her caregiver, facing a TV monitor. The caregivers were instructed not to communicate with their infants, through either vocalization or movements, during the experiment. Prior to the test trials, infants in the experimental groups participated in a 1-min familiarization period.[5] Infants in the control group received only test trials. Infants in the interactive condition were shown a person playing with Robovie, which reacted to the person (Fig. 2A) with gestures and speech. For example, when the person stood over the robot, the robot responded by saying, “What? May I play with you?” If the person replied, “Yes, please,” the robot said, “What are you playing with me?” In the non-active robot condition, the robot remained stationary and did not react to the person who behaved as she had behaved in the interactive condition

[5] During the familiarization period and the test trials, the actors and the robot talked to each other in Japanese.

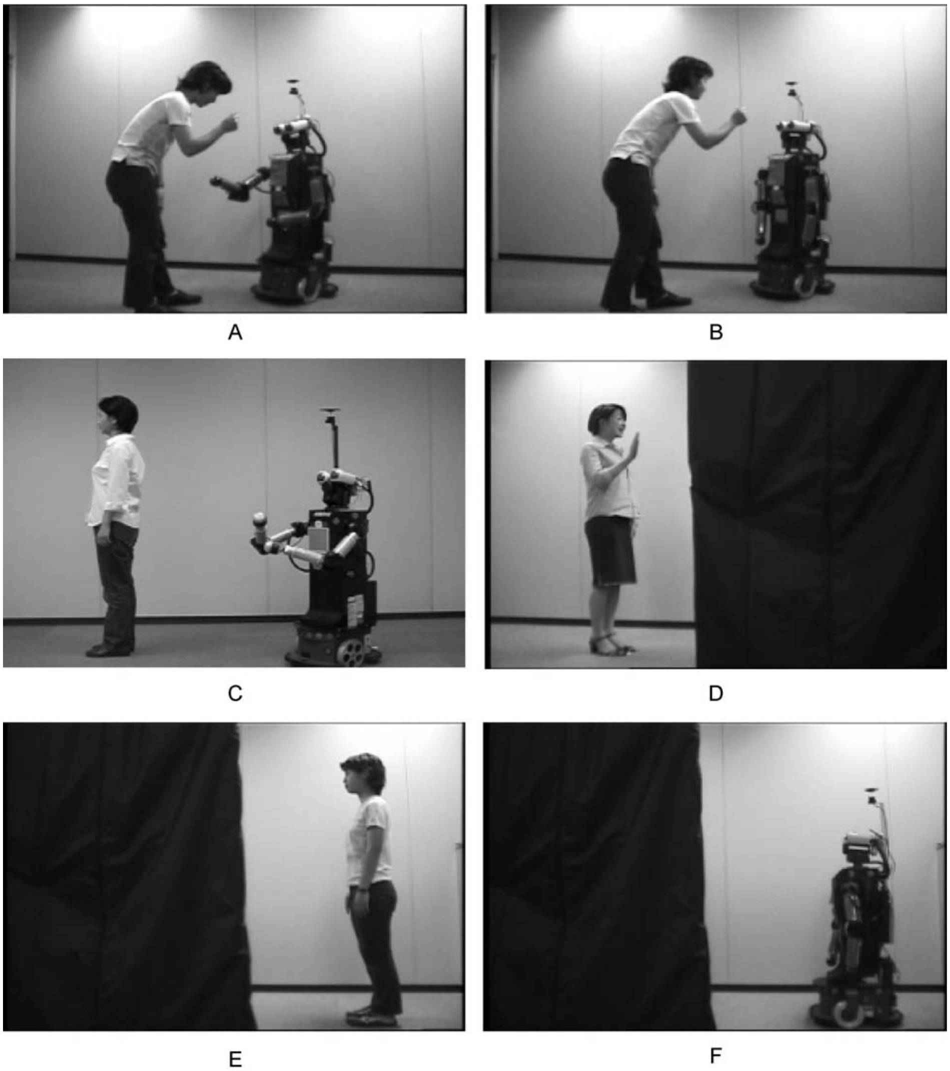

Fig. 2. The familiarization period in (A): the interactive robot condition, (B): the non-active robot condition, and (C): the active robot condition. In the test trials, (D): A new actor talking and appearing (E): the person, and (F): the robot.

(Fig. 2B). In the active robot condition, the robot behaved like a person while the person remained stationary and did not respond (Fig. 2C). Following the familiarization period, the monitor went dark for 2 s, and then the test trials began.

During the test trials, an actor talked to something hidden behind a curtain (Fig. 2D). The curtain was then opened for 2 s, and either the person or the robot appeared (Fig. 2E and F). Each infant viewed six test trials, which alternated three trials with the person and three with the robot. The order of the stimuli (person first or Robovie first) and the position of the actor (left or right) were counterbalanced across subjects.

2.4. Measures and scoring

The looking behavior of each infant was recorded with a CCD camera (Sony: CCD-MC100) on a Digital Video-recorder (Sony: GV-D900), and responses were scored by a primary coder who was blind to the experimental conditions. The coder recorded the length of time each infant spent looking at the stimulus during the familiarization period and the test trials.

For each condition, the coder recorded the duration of looking from the infant's first fixation until the infant looked away from the stimulus for longer than 2 s. The secondary coder recoded 10% of the data, and reliability of the duration of looking was measured using Cohen's kappa ($k=0.90$).

3. Results

3.1. Familiarization period

During the familiarization period, infants' looking time averaged 45 s (SD = 9.7) in the interactive robot condition, 42 s (SD = 5.7) in the non-active robot condition, and 48 s (SD = 5.2) in the active robot condition. A one-way analysis of variance (ANOVA) was conducted to determine whether the infants in the three conditions had similar attention levels measured by looking time during the familiarization period. There were no significant main effects within the familiarization period, [F (2, 33) = 2.38, NS].

3.2. Test trials

The mean looking times to the person and to the robot under each of the four conditions (interactive robot, non-active robot, active robot, and control) are shown in Fig. 3. A within-subjects, 3 (trial pair) × 2 (stimuli) repeated measures ANOVA was conducted on infants' looking times for each of the four conditions. There were no significant effects in the interactive group [F (1,11) = 0.014, NS]. However, in the non-active robot group, infants looked longer at the robot than at the person [F (1,11) = 7.8, $P=0.018$]. Infants also looked longer at the robot than at the person in the active group [F (1,11) = 18.1, $P=0.001$], and subjects in the control group performed similarly [F (1,11) = 12.6, $P=0.005$].

Infants in the interactive robot conditions looked at the robot as long as they looked at the person, implying that infants in the interactive robot condition expected the robot to be talked to by the person. However, infants in the three experimental conditions looked longer at the robot than at the person, suggesting that infants in these non-interactive robot conditions did not expect the robot to be talked to by the person.

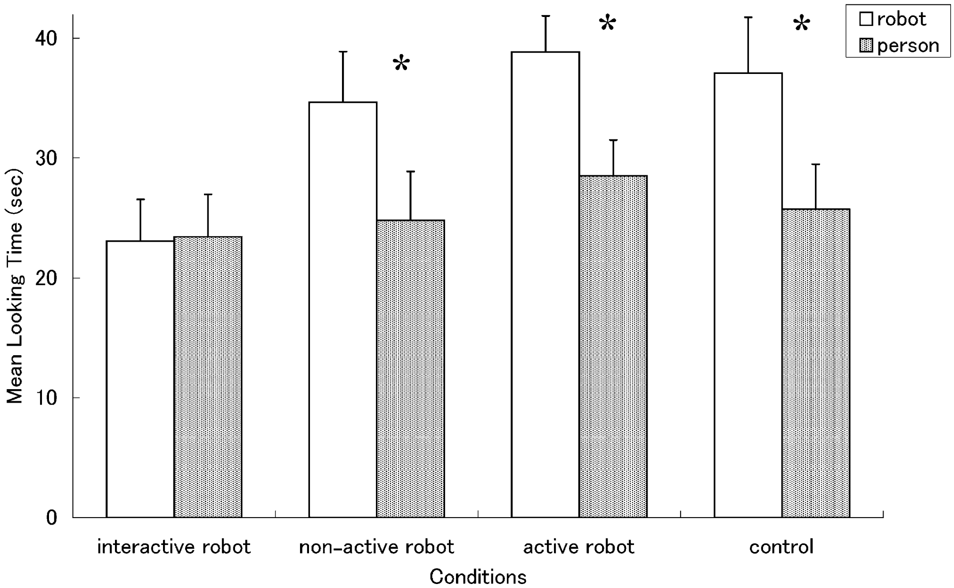

Fig. 3. Mean looking times for the person and the robot during test periods for the interactive robot, non-active robot, active robot, and control conditions. (*$P<0.05$).

4. Discussion

The purpose of this study was to determine whether infants think of humanoid robots as communicative agents. Recently, Legerstee et al. (2000) demonstrated that infants expect people to communicate only with people and not with non-human objects. However, the question of how infants characterize objects that behave like humans had not been resolved. Using a similar approach to Legerstee et al. (2000), we investigated whether infants expect people to talk to humanoid robots. In this study, there were four conditions, three of which included a familiarization period in which the infants observed the robots' actions. In the interactive robot condition, the robot behaved like a person and interacted with the person. In the non-active robot condition, the robot remained stationary and did not respond to the person talking to it. In the active robot condition, the robot displayed humanlike behaviors but did not interact with anyone. The control condition did not include a familiarization period. In the test trials, all infants watched another actor talk to the person and to the robot. If the infants expected the robot to be talked to by a person and characterized the robot as a communicative agent, they would not be surprised by the one-sided conversation. If the infants did not expect the robot to be talked to by persons, and characterized the robot as an object, they would be surprised.

During the familiarization period, the infants' looking-time did not differ among the three conditions. This was counterintuitive to our expectation that infants in the interactive robot condition would spend more time looking than infants in the non-active robot and active robot conditions, because there were two active objects in the interactive robot condition (the robot and the person), as compared to one in the other conditions (only the robot or the person). We suspect that this result arises from a short familiarization period.

Data from the control group suggests that infants who were naïve about robots did not expect the robot to be talked to by a person, and that infants regarded the robot as an object.

Results from the non-active robot condition suggest that infants did not expect the robot to be talked to by the person, even though they had observed that another person talked to the robot during the familiarization period. This suggests that infants do not regard the non-active robot as a communicative agent even if humans talk to it. The suggestion is quite opposite to a simple associationist view that if infants are familiar with a scenario in which persons talk to non-human objects, then they learn and expect those objects to be talked to by persons.

In addition, the results in the active robot condition suggest that infants did not expect the robot to be talked to by a person, even though they had previously observed the robot being active like a human, but being non-interactive with a human. This result implies that infants do not regard human-likely active robots as communicative agents. This implication is similar to the previous study that used a small radio-controlled toy (Poulin-Dubois, Lepage, & Ferland, 1996).

The most interesting result of the present study is that infants in the interactive robot condition expected the robot to be talked to by a person. Infants seem to regard interactive robots as communicative agents when they have previously viewed human–robot interactions.

Our findings suggest that infants interpret only the interactive humanoid robot as a communicative agent, and that infants characterize non-interactive humanoid robots as objects. It is necessary for human and robot to interact for infants to attribute a mentality to the robots. The previous studies that used a box-shaped robot or a stuffed toy (Movellan et al., 1987; Johnson et al., 1999) indicated that infants follow the gaze of non-human objects when such objects are interactive with humans. Our findings are in agreement with these findings; however, the present study suggests the possibility that non-human objects may be characterized as social agents if infants can perceive such interactive humanoid robots as capable of communicating with people.

Several studies of theory of mind in infancy have shown that infants discriminate between people and objects and do not attribute mental states to objects, even when such objects look like people or are self-propelled (Legerstee, 1994, 1997; Poulin-Dubois et al., 1996). In contrast, the results of this study, as well as those of Johnson et al. (1999, 2002) and Movellan and Watson (1987), suggest that infants respond to interactive objects as mentalistic agents like people. We think that these inconsistencies are attributed mainly to objects' communicative cues, such as interactivity of objects. Communicative cues do let humans regard objects as highly mentalistic, communicative agents, while simply self-propulsion does not. In the future, if infants live and grow in the society where people talk to and communicate with robots that resemble and behave like real human beings, will they regard those artificial objects as having a mind? Future work should examine long-term interactions between infants and robots as well as the effects of specific morphological features and actions of objects on infant cognition.

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