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Young Children Treat Robots as Informants

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Abstract

Children ranging from 3 to 5 years were introduced to two anthropomorphic robots that provided them with information about unfamiliar animals. Children treated the robots as interlocutors. They supplied information to the robots and retained what the robots told them. Children also treated the robots as informants from whom they could seek information. Consistent with studies of children's early sensitivity to an interlocutor's non-verbal signals, children were especially attentive and receptive to whichever robot displayed the greater non-verbal contingency. Such selective information seeking is consistent with recent findings showing that although young children learn from others, they are selective with respect to the informants that they question or endorse.

Keywords: Social robots; Non-verbal communication; Contingent behavior; Social judgments; Preschool children

1. Introduction

Young children explore their environment, experiment with it, and learn from their own, first-hand observations, but they are also social learners who gather information from other people. Such receptivity to information provided by others is likely to have played a crucial role in human evolution (Nielsen, 2012; Richerson & Boyd, 2005). We ask how far children display this receptivity to socially transmitted information when they interact with a robot rather than a human being. In learning from others, children are also selective. They are willing to accept information from some informants more than others (Harris, 2012). Accordingly, we ask whether children are not only receptive, but also

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selective in their response to robots as informants. More specifically, we ask if they prefer to learn from a robot that displays specific social characteristics.

So far, contemporary research on child–robot interaction has shown that children readily treat anthropomorphic robots as social companions. For example, when robots interacted via gestures and utterances with visitors to a science museum, children—and indeed adults—judged them to be interesting and friendly. Moreover, children displayed an interest in museum exhibits after being led to them or having them explained by the robot (Shiomi, Kanda, Ishiguro, & Hagita, 2006). Kahn and colleagues extended those initial findings by showing that when interacting with robots playing the role of aquarium guide, children often went beyond the type of limited verbal response that one might give to an automated voice system on the telephone (Kahn et al., 2012). This study also revealed that most children judged Robovie (the robot in question) to possess various mental attributes (e.g., to be capable of feeling interested or sad), various social attributes (e.g., to be capable of social interaction and friendship), and to have moral rights (e.g., deserving to be treated fairly and not exploited).

Taken together, these studies show that young children readily engage with robots as friendly companions and guides in an unfamiliar environment. In this study, we build on these findings by asking how far children will not only follow and listen to a robot, but also learn and retain new information from a robot. In both of the studies just described, the robots provided information about visible displays such as a museum exhibit or an aquarium as well as their own interests and preferences. It is plausible, therefore, that children construed the robots not just as friendly companions, but also as knowledgeable informants from whom they could acquire new information about the objects or creatures on display in the museum. However, no assessments were made of children's learning from the robots.

Movellan, Eckhardt, Virnes, and Rodrigues (2009) did assess children's learning from a robot. Toddlers aged 18–24 months interacted with a sociable robot, RUBI. On any given trial, RUBI displayed images of four objects on a 12-inch touch screen located on its body and asked the child to touch one of the displayed objects (e.g., "Touch the orange"). At pre-test, children's choices were little better than chance. Over a 2-week period, they showed significant improvement on taught words, but no improvement on control words. These results demonstrate modest learning, but they cast no light on how RUBI was construed by children. Arguably, they conceptualized RUBI simply as a display screen with a recorded voice but not as an informative interlocutor whom they could question and learn from.

Suggestive evidence was also reported by Tanaka and Matsuzoe (2012). Children ranging from 3 to 6 years learned the meaning of some novel action words in the company of a robot. The robot either responded correctly or incorrectly to test questions about the novel words. Children were quite responsive when the robot responded incorrectly—they often touched or spoke to the robot, suggesting that they construed the robot as cognitively similar to a human peer in being able to take in, and benefit from, informative feedback. However, because the children's utterances were not analyzed, it is unclear whether this "rich" interpretation is appropriate. Children may have been simply trying to offer reassurance or consolation to an error-prone companion.

Recent developmental research has highlighted young children's receptivity to the testimony that other people can provide about absent or hard-to-observe objects and properties (Harris & Koenig, 2006). Nevertheless, children differentiate among informants in various ways. For example, 3- to 5-year-olds typically prefer to learn from informants who are familiar to them (Corriveau & Harris, 2009) or share identifiable social markers with them such as accent (Kinzler, Corriveau, & Harris, 2010). Children's receptivity to information provided by an interlocutor might make them receptive to information provided by a robot. On the other hand, their differentiation among potential informants might render children unwilling to learn from a relatively unfamiliar robot with a novel accent. In this study, we assessed whether children learn and retain information from a robot and also whether they are more receptive if the robot displays the kind of contingent attentiveness that ordinarily characterizes human conversation.

Human communication, including non-verbal communication, calls for appropriate turn-taking and social responsiveness. Even pre-verbal infants are sensitive to whether a "conversation" partner shows well-timed responsiveness to his or her signals (Murray & Travarthen, 1985; Nadel, Carchon, Kervella, Marcelli, & Réserbat-Plantey, 1999). Indeed, Kuhl (2007) has proposed that such contingent responsiveness is an essential precondition for certain types of language learning in infancy. Accordingly, the contingent responsiveness of the two robots was manipulated by making one robot respond contingently; it conveyed attentiveness via appropriate gaze direction and bodily orientation whenever the child or the experimenter spoke. By contrast, the other robot responded non-contingently; it did not signal attentiveness when either the child or the experimenter spoke.

We invited children aged 3–5 years to interact with the two concurrently presented robots. In the course of the interaction, children were invited to talk about their favorite animal and then each robot shared information about its favorite animal. Children were later invited to recall the information that each robot had shared. Children were also given an opportunity to seek information about an unfamiliar animal from one of the two robots, and to indicate which of the robots' conflicting claims they endorsed. Children's liking for the two robots was assessed via several different measures. Finally, children's gaze behavior during the interactions with the robots was recorded and analyzed.

The study was designed to examine three questions. First, we asked if young children are willing to learn new information from an anthropomorphic robot. More specifically, we asked if preschool children would learn the names and properties of the unfamiliar animals described by each robot.

Second, we asked if children would regard the two robots as equally reliable informants. To answer this question, we examined whether children were willing to seek and endorse information from the two robots to the same extent or whether they preferred to seek and endorse information from the contingent rather than the non-contingent robot.

Third, we asked how far children would differentiate between the two robots as companions. Arguably, the opportunity to listen to, and share information with, either robot would be sufficient for children to regard that robot as a companion. Alternatively, children might prefer to interact with whichever robot displayed greater contingent responsiveness. To answer this question, we compared children's liking for the two robots.

Finally, the analysis of children's gaze offered an additional opportunity to pinpoint any differentiation they might make between the contingent and the non-contingent robot during their interaction with them.

2. Method

2.1. Participants

The 17 children (8 female, 9 male) ranged from 3 to 5 years, with a mean age of 4.2 years (*SD* = .79). The children were recruited from a preschool in the Greater Boston area serving a predominantly middle-class population.

2.2. Robots

The robots used were DragonBots (pictured in Fig. 1), medium-sized robotic creatures designed to be appealing to children (Freed, 2012; Setapen, 2012). The robots each contain a smartphone, which runs control software and displays the robot's animated face. Sensors in the phone (e.g., microphone, camera) stream data to a remote human operator, who uses a computer interface to trigger the robot's speech, movements, and facial expressions. Both operators followed a strict script in triggering their robots' behavior. The operator of the socially sensitive, contingent robot was instructed to make the robot

Fig. 1. Interacting with the two robots.

respond as naturally and socially as possible. The operator directed the robot to look at whoever was speaking, to attend to the child when it (i.e., the robot) was speaking, and to glance down at any objects being discussed.

For the "insensitive," non-contingent robot's behavior, we recorded the actions triggered by the contingent operator during the previous experimental session and played them back with randomly determined timing. This ensured that both robots performed a comparable number of actions. However, the robot was directed to look at the child when it was speaking, but to look in randomly determined directions the rest of the time. So, from the perspective of an adult, the robot appeared to be engaged in the conversation if it was speaking but to be disengaged if either the experimenter or the child was speaking.

2.3. Procedure

All children were tested in the familiar setting of their preschool. A female experimenter led them to a quiet area where two anthropomorphic robots, one with yellow fur the other with green fur, were positioned on a table facing a set of five familiar toy animals (see Fig. 1). Each robot greeted the child as s/he approached: "Hi! My name is Green. I'm very happy to meet you." "Hi! My name is Yellow. I'm excited you came to play with us." The experimenter then explained: "Green and Yellow like to play with toy animals. We're going to ask them about their favorite animals later. But first, (Name of child) can you choose your favorite toy animal and tell Green and Yellow all about it?" Children who failed to elaborate were prompted with questions (e.g., about where their favorite animals lived, what they liked to eat, etc.).

The experimenter then removed the five familiar animals and replaced them with a tray containing each robot's favorite animal. These were exotic animals unlikely to be familiar to any of the children. One robot said, looking at the relevant toy animal on the table and then at the child: "My favorite animal is the loma! I like how it's white with such big antlers! Did you know it can go for weeks without drinking water? Do you like the loma?" The other robot said, again looking at child and then the relevant toy animal: "My favorite animal is the mido! I like how it's black and its horns are curvy! Did you know it only eats leaves and grass? Do you like the mido?" The robots used unfamiliar bi-syllables to name the animals, rather than the actual names, to ensure that both names would be easy for children to encode and pronounce. Note that neither the robots nor the experimenter handled the animals while this information was provided. However, mimicking ordinary human communication, each robot oriented toward its favorite animal when describing it.

Next, the experimenter explained that the two robots needed to rest and invited children to draw a picture of one of them using the drawing materials at a nearby drawing area. Once their drawing was complete, children were invited to show their drawing to one of the robots.

Next, a tray of three animals—Green's favorite animal, a similar-looking distractor, and a dissimilar distractor—was presented and children were invited to point to, and name, the animal that was Green's favorite. The same procedure was then administered for Yellow's favorite animal. Subsequently, the experimenter removed the trays, moved the robots' favorite animals to a table in front of the robots, and with respect to each of the two animals, either endorsed or corrected the child's response and asked if children remembered what the relevant robot had said about it: "You're right/Actually, this is Green's/Yellow's favorite animal. Can you remember what Green/Yellow said about this animal?" Children were then asked which of these two animals they liked best.

The experimenter produced one additional animal, commented on its unusual appearance, and asked what it was called: "But look at this funny animal . . . I don't know what this animal is called. Do you know . . .?" With the exception of one child who claimed that it was a bear (and was corrected), all children said that they did not know. Children were then prompted to ask one of the robots: "Hmm, I tell you what, let's ask Green or Yellow. Who do you think we should ask?" The child picked a robot. Irrespective of which robot the child selected, each robot made a different claim. One said: "That's a capy!" whereas the other said: "That's a poba!" The experimenter re-stated what each robot had said and asked: "What do you think?"

Finally, the experimenter said that time was up and invited the children to say goodbye to the robots. In an area away from the robots, the experimenter showed the children two sticker boxes, one belonging to each robot. The children were given five stickers to give to the two robots, dividing them as they saw fit. Finally, the children were asked how much they would like to come back and play again with each robot: "A lot, a little bit, or not very much?"

Throughout the interaction, the two robots produced non-verbal movements (head movements, gaze shifts, arm movements, and facial movements) that are typical for ordinary human face-to-face interaction. However, the two robots also differed in subtle but detectable ways. As noted above, one robot attended in a contingent fashion (as signaled via head and gaze orientation) to the child or the experimenter when either of them spoke. By contrast, the attention of the other robot was not contingently directed at the child or at the experimenter when either of them spoke. Thus, from the standpoint of adult onlookers, the two robots appeared to differ in how much they were involved as listeners in the ongoing conversation. The contingent robot gave the impression of being engaged, whereas the non-contingent robot gave the impression of being disengaged.

The name and color of the contingent versus non-contingent robot was systematically varied across participants.

2.4. Dependent variables

2.4.1. Information recall

We recorded whether or not the child could point to the favorite animal of each robot and name it correctly. Children were also given a score from 0 to 3 for the number of facts that they remembered from the description provided by each robot about its favorite animal.

2.4.2. Seeking and endorsing information

We recorded which robot children preferred to ask for the name of the unfamiliar animal, and which of the two different names they endorsed.

2.4.3. Liking/preference

We noted which robot the child wanted to draw, to whom the child wanted to show the picture, as well as which of the two favorite animals the child preferred. Children were given a score of 3, 2, or 1 depending on whether they said that they would want to come back to play with each robot a lot, a little bit, or not very much. Lastly, we noted the number of stickers the child gave to each robot (from 0 to 5).

2.4.4. Non-verbal measures

Using video recordings of children's interactions with the robots, we measured the amount of time each child spent looking at: (a) the contingent robot; (b) the non-contingent robot; and (c) elsewhere. We also coded behaviors such as touching or petting the robot, but these behaviors occurred so rarely that we do not report any further results regarding these behaviors.

3. Results

3.1. Information recall

Children were quite good at recalling information supplied by each robot. Thus, most children correctly indicated which animal was the robot's favorite, both for the contingent robot (88.2% correct choice; 0.0% similar distractor; and 11.8% dissimilar distractor) and the non-contingent robot (94.1% correct choice; 0.0% similar distractor; 5.9% dissimilar distractor). Binomial tests confirmed that the number of children making a correct as opposed to an incorrect choice was greater than chance ($p < .001$, for each robot). Surprisingly, no children recalled the names of the animals.

With respect to the facts supplied about the favorite animal of the contingent robot, six children recalled no facts (35.3%), five recalled one fact (29.4%), six recalled two facts (35.3%), and none recalled three facts (0.0%). Eight children recalled that the fact about antlers (47.1%), six children recalled the fact about the animal's color (35.3%), and two children recalled the fact about what the animal ate or drank (11.8%). With respect to the favorite animal of the non-contingent robot, four children recalled no facts (23.5%), eight recalled one fact (47.1%), four recalled two facts (23.5%), and one recalled three facts (5.9%). Nine children recalled that the fact about antlers (52.9%), seven children recalled the fact about the animal's color (41.2%), and two children recalled the fact about what the animal ate or drank (11.8%). Thus, of the three facts supplied by each robot, the majority of children recalled at least one fact, and approximately one-third recalled two facts. No statistically reliable differences were revealed in the number or type of facts recalled from the contingent as compared to the non-contingent robot. Moreover, irrespective of which robot had supplied them, certain facts emerged as more memorable than others.

3.2. Seeking and endorsing information

With respect to seeking information about the novel animal, significantly more children chose to ask the contingent robot (82.4%) than the non-contingent robot (17.6%), Binomial test, $p < .013$. In addition, more children endorsed the name given by the contingent robot (64.7%) than by the non-contingent robot (17.6%), Binomial test, $p < .057$. Note that three children (17.6%) either did not respond to the endorsement question or insisted that the novel animal had another name entirely.

3.3. Liking/preference

Turning to the liking/preference measures, children showed no statistically reliable systematic preference for one of the robots with respect to: (a) which robot they drew (3 children drew the contingent robot; 6 drew the non-contingent robot; 4 drew both robots; and 5 drew neither robot or did not draw at all); (b) to whom they showed their drawing (5 showed the contingent robot; 6 showed the non-contingent robot; 5 showed both robots); (c) which of the two favorite animals they said they preferred (8 preferred the favorite animal of the contingent robot; 7 preferred the favorite animal of the non-contingent robot; 2 children chose both); and (d) the number of stickers they offered to each robot ($M = 2.38$, $SD = 1.15$ offered to contingent robot; $M = 2.44$, $SD = 1.15$ offered to non-contingent robot).

Note, however, that this failure to profess a systematic preference was not due to indifference or dislike because children expressed equally high levels of interest in playing with each of the two robots in the future. Thus, with respect to whether they wanted to return to play with the contingent robot, 12 children said "a lot," 4 children said "a little," and 0 children said "not very much"; for the non-contingent robot, 14 children said "a lot," 1 child said "a little," and 1 child said "not very much."

3.4. Non-verbal measures

During the 6-minute duration, children looked significantly more at the contingent ($M = 97$ s, $SD = 21$ s) than the non-contingent robot ($M = 82$ s, $SD = 17$ s) ($t(16) = 3.42$, $p = .004$, $d = 0.83$). To further understand, this overall difference, we examined how long children looked at each robot: (a) when either of the two robots was talking; (b) when the child was talking; and (c) when the experimenter was talking. When either robot was talking, children tended to look at that robot to the same extent: $M = 26$ s, $SD = 6$ s for the contingent robot and $M = 24$ s, $SD = 6$ s for the non-contingent robot. When children were talking, they spent approximately the same limited amount of time looking at the contingent robot ($M = 7$ s, $SD = 5$) as the non-contingent robot ($M = 6$ s, $SD = 4$). However, when the experimenter was talking, children spent significantly more time looking at the contingent robot (M = 58 s, SD = 20 s) than at the non-contingent robot (M = 46 s, SD = 13 s), $t(16) = 2.68$, $p < .02$, $d = 0.65$).

In summary, when either robot spoke, it tended to attract and hold children's attention. When children were speaking themselves, they rarely looked at either robot. Finally, when both robots were silent, and the experimenter held the floor, children often looked at the robots, but they spent more time looking at the contingent robot than the non-contingent robot.

4. Discussion

The findings provide answers to the three questions raised in the introduction. First, we obtained evidence that preschoolers are willing to treat a robot as a knowledgeable and informative interlocutor. Admittedly, children had difficulty in recalling the names of the robots' favorite animals, but each name was stated only twice and other evidence indicates that children are not always successful at such "fast-mapping" even when they engage with a human interlocutor (Wilkinson, Ross, & Diamond, 2003). Nevertheless, children could accurately distinguish the robots' favorite animals from other animals, including similar-looking distractors. In addition, the majority of participants remembered at least one fact supplied by each robot about that favorite animal.

Second, although children learned from both robots, they displayed a preference for the contingent robot as an informant. Thus, when given the choice, they preferred to seek and endorse information from the contingent rather than the non-contingent robot.

Finally, children responded to both robots as likeable companions. They showed no obvious preference for either robot as indexed by which robot they chose to draw, which robot they showed their drawing to, and the number of stickers they shared. Indeed, at the end of their brief interaction, when asked whether they wanted to return to play again with both the contingent and the non-contingent robot, most children said that they wanted to do so "a lot" with respect to each robot.

Overall, this pattern of findings suggests that children's preference for the contingent robot over the non-contingent robot as an informant was not a simple result of which robot was better liked as a potential companion. Rather, it suggests that children—arguably outside of any conscious awareness—were sensitive to the social responsiveness of each robot and perceived the robot that embodied greater contingency to be a superior conversation partner and informant. Consistent with this interpretation, during those intervals in which the experimenter was speaking so that neither the child nor the robot held the floor, children were more likely to look at the contingent robot than the non-contingent robot. Presumably, children were sensitive to the fact that the contingent robot, via gaze direction and bodily orientation, signaled greater engagement with what was being said. Though preliminary, these findings suggest that much of the widely reported failure of technological entities to "teach" young children effectively might stem from their one-sided animacy. That is, although these entities appear to be "alive" and may even be regarded as likeable companions by young children, they lack a fundamental aspect of human interaction in a learning environment: the contingent responsiveness that is displayed by an engaged interlocutor. At the same time, our results also suggest that children prefer to learn from a robot that displays contingent responsiveness. In future research, it will be informative to explore the early emergence of such learning preferences. Research with infants has shown that they are sensitive to contingent responsiveness in a "conversation" partner (Murray & Trevarthen, 1985); they also discriminate among potential informants (Harris & Lane, 2013). Hence, it is plausible to expect that when infants have an opportunity to seek information from a robot, they too, like the preschoolers assessed in this study, will prefer to learn from a robot displaying contingent responsiveness.

Classic research on cognitive development has often portrayed children as relatively autonomous theorists (Wellman & Gelman, 1992). However, as noted in the introduction, children's receptivity to information provided by other people is likely to have played a key role in human evolution, especially with respect to humans' distinctive reliance on culturally transmitted skills and knowledge (Richerson & Boyd, 2005; Whiten, 2013). In this context, children's selective receptivity to the testimony and demonstrations provided by other people is receiving increasing attention in developmental psychology (Harris & Corriveau, 2011). Future research should be able to establish the conditions under which children display a similar type of selective receptivity when they interact with a robot rather than a human being. Our results suggest that the contingent responsiveness of the robot is likely to be one important contributor to such receptivity.

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