Early Education and Development

ISSN: 1040-9289 (Print) 1556-6935 (Online) Journal homepage: http://www.tandfonline.com/loi/heed20

Children's Cognitive and Behavioral Reactions to an Autonomous Versus Controlled Social Robot Dog

Nadia Chernyak & Heather E. Gary

To cite this article: Nadia Chernyak & Heather E. Gary (2016): Children's Cognitive and Behavioral Reactions to an Autonomous Versus Controlled Social Robot Dog, Early Education and Development

To link to this article: http://dx.doi.org/10.1080/10409289.2016.1158611

EARLY EDUCATION AND DEVELOPMENT
http://dx.doi.org/10.1080/10409289.2016.1158611

Routledge
Taylor & Francis Group

Children's Cognitive and Behavioral Reactions to an Autonomous Versus Controlled Social Robot Dog

Nadia Chernyak [a] and Heather E. Gary[b]

[a]Department of Psychological and Brain Sciences, Boston University; [b]Department of Psychology, University of Washington, Seattle

ABSTRACT
Research Findings: Interactive technology has become ubiquitous in young children's lives, but little is known about how children incorporate such technologies into their intuitive biological theories. Here we explore how the manner in which technology is introduced to young children impacts their biological reasoning, moral regard, and prosocial behavior toward it. We asked 5- and 7-year-old children to interact with a robot dog that was described either as moving autonomously or as remote controlled. Compared with a controlled robot, the autonomous robot caused children to ascribe higher emotional and physical sentience to the robot, to reference the robot as having desires and physiological states, and to reference moral concerns as applying to the robot. Children who owned a dog at home were more likely to behave prosocially toward the autonomous robot than those who did not. *Practice or Policy*: Recent work has begun to use robots as learning tools. Our results suggest that the manner in which robots are introduced to young children may differentially impact children's learning. Presenting robots as autonomous agents may help promote children's social-emotional development, whereas presenting robots as human controlled may help promote robots as purely cognitive educational tools.

> It's a machine, Schroeder. It doesn't get pissed off, it doesn't get happy, it doesn't get sad, it doesn't laugh at your jokes …
>
> —*Short Circuit* (1986)

At the crux of the classic movie *Short Circuit* lay the philosophical dilemma of whether a robot, Number 5, should be saved from disassembly. Some felt that Number 5 had displayed emotional sophistication, proving it worthy of moral regard, whereas others felt that Number 5 was merely a tool, no more worthy of being helped than a stereo or a vacuum cleaner.

Although such philosophical dilemmas are most dramatically portrayed in movies, determining who and what is worthy of moral regard is a critical cognitive achievement. In the present day, young children are increasingly bombarded with interactive social technologies (e.g., Furbys, iPads, Roomba vacuum cleaners, Siri) that are designed to interact with humans in a range of lifelike ways, some of which include the ability to move around autonomously (Kahn, Gary, & Shen, 2013). Given their relative historical novelty, the manner in which such technologies are presented to young children is understudied. Thus, little is known about how presenting technology to young children impacts their conceptions of and regard for it. In this work, we explore how a brief 5-min interaction with either an autonomously moving or controlled robot impacted children's beliefs in the robot as a

CONTACT Nadia Chernyak chernyak@bu.edu Department of Psychological and Brain Sciences, Boston University, 64 Cummington Mall, Boston, MA 02215.

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/HEED.

Supplemental data for this article can be accessed on the publisher's website.

sentient being, endorsement of the robot as having moral standing, and prosocial behavior toward the robot.

Our research question was motivated by two concerns. First, our work aimed to understand the developing link between people's moral cognition and their understanding of others as sentient beings (see Gray, Gray, & Wegner, 2007, and Sytsma & Machery, 2012, for demonstrations of this link with adults). Although much is known about children's naïve biological theories about nature, plants, animals, and agents, less is known about their understanding of interactive technologies (Inagaki & Hatano, 2002). Robots share similarities to agents across a wide array of features. A large body of literature has found that even in infancy, children make social evaluations of entities based on features such as eyes (Hamlin, Wynn, & Bloom, 2007), contingent interaction (Beier & Carey, 2014; Johnson, Slaughter, & Carey, 1998), and/or goal-directed movement (e.g., Gergely & Csibra, 2003; Heider & Simmel, 1944; Saxe, Tenenbaum, & Carey, 2005; Sommerville, Hildebrand, & Crane, 2008; Woodward, Sommerville, Gerson, Henderson, & Buresh, 2009; see also Gao, McCarthy, & Scholl, 2010, for a demonstration with adults). In fact, many studies on infant cognition arguably use social robots (e.g., Beier & Carey, 2014). Interactive technologies present a unique problem, as they often display all of these cues and yet, at least by adults, are not considered to be sentient beings worthy of moral regard (Gray et al., 2007; Jipson & Gelman, 2007). Therefore, another possibility is that higher order concerns, such as whether an entity is alive, sentient, or autonomous, play into children's moral regard for it.

Second, we aimed to disambiguate prior work examining children's conception of social robots. On the one hand, when prompted to interact with and talk about social robots, children have been known to show a domain confusion and fail to conceptualize robots neatly as the artifacts they are or the living beings they emulate (Crick & Scasselatti, 2010; Kahn, Friedman, Perez-Granados, & Freier, 2006; Kahn et al., 2012). Such work has largely focused on children's ability to form relationships with robots and thus conceive of them as moral and social beings. On the other hand, when asked forced choice questions about robots' basic biological and psychological properties, children appear to understand that robots lack such properties and thus separate robots from prototypically living entities such as rodents or degus (Jipson & Gelman, 2007).

One possibility for the seemingly disparate results may therefore concern the difference between behavioral, explanatory, and forced choice responses (see Wellman, 2011). Another possibility is that children may understand robots as nonliving but nonetheless be unable to inhibit their moral regard for them. After all, children have been shown to be prosocial even toward animal puppets (e.g., Aknin, Hamlin, & Dunn, 2012; Chernyak & Kushnir, 2013; Vaish, Missana, & Tomasello, 2011). Finally, yet another possibility, and one that we were most interested in exploring, is that the manner in which robots are presented to young children can have important consequences for how they are conceptualized. In an important demonstration, Somanader, Saylor, and Levin (2011) showed that preschool-age children ascribed biological capacities to robots, but not when the mechanism controlling the robots (i.e., remote control) was made apparent (see also Gelman & Gottfried, 1996). Here we used a similar manipulation to examine children's understanding of robots across a broad battery of questions (forced choice, explanatory, and behavioral).

In this study, we asked two groups of children, 5-year-olds and 7-year-olds, to interact with a social robot that appeared to move in one of two ways: either in a *controlled* manner (via a remote control held by the experimenter) or *autonomously* (with no remote present). We chose these age groups on the basis of prior work, which has found that the ages of 4–7 are associated with changes in children's perceptions of robots (Bernstein & Crowley, 2008) and children's abilities to share fairly (e.g., Smith, Blake, & Harris, 2013).

We expected that children would be likely to view the autonomous robot as sentient (i.e., possessing physiological and emotional capacities typically indicative of animals) and worthy of moral regard despite the fact that the surface behaviors of the robots were identical across conditions. To test this prediction, we introduced children to the robot and then assessed their beliefs about four dimensions related to moral regard: (a) emotional/psychological sentience, (b) physical sentience, (c) moral standing, and (d) prosocial behavior. The first three dimensions were assessed through both forced choice and explanatory responses; the final dimension was assessed through behavioral responses.

Method

Participants

Participants were 80 children (forty 5-year-olds: $M = 5.50$, $SD = 0.30$; forty 7-year-olds: $M = 7.35$, $SD = 0.36$; 50% female) recruited from a summer camp in Colorado. Participants were of predominantly Euro-American, middle-class background. Children were tested individually in a quiet corner. One child was excluded from final analyses because of limited English production and comprehension. All sessions were audiotaped for later coding.

Experience With Real Dogs

Prior work has found that experience with novel entities changes people's conception of them (see Inagaki & Hatano, 2002). In this case, we introduced children to an entity (the social robot dog) with which none of them were familiar and that thus was presumably entirely novel to the young children. However, children's understanding of a robotic dog may nonetheless depend on their prior experience with real dogs (perceptually similar agents). All children were thus asked whether they had a real dog at home. Approximately half ($n = 37$) of the children indicated having one.

Interaction

All children then took part in a 5-min interaction with a robot dog, AIBO (see Figure 1). The robotic dog is not commercially available, and thus it was unlikely that children had had any previous interaction with it. Children were first shown the robot and informed that they would be playing with it. All children then watched AIBO engage in a series of preprogrammed behaviors: waking up (stretching), sitting down, kicking a ball, head-butting a ball, moving its head around, walking, making sounds, whistling, shaking its head, giving a high five, giving a paw, and waving hello.

Figure 1. The robot dog AIBO tracks a pink ball.

Manipulation

Children were randomly assigned to one of two conditions. A total of 41 children (*autonomous condition*) heard the experimenter narrate AIBO's behavior in a way that was consistent with autonomous movement (e.g., "AIBO is kicking the ball") The other half (39 children; *controlled condition*) saw AIBO engage in identical behaviors, but the experimenter held a video game controller in plain view of the children and narrated AIBO's behavior in a manner consistent with controlled movement (e.g., "I made AIBO kick the ball"). The language we used in this condition implied that the agent *forced* AIBO to kick the ball. There were equal distributions of age groups and genders in each condition.

Dependent Measures

We inquired about four dimensions related to children's moral regard: (a) emotional sentience, (b) physical sentience, (c) moral standing, and (d) prosocial behavior. Questions were adapted from prior work assessing children's conceptualization of robotic others (Jipson & Gelman, 2007; Kahn et al., 2006, 2012), moral reasoning (Smetana, 1983), and prosocial behavior (Chernyak & Kushnir, 2013). The questions and coding scheme are described here and shown in full in Table 1.[1]

Physical Sentience

We assessed beliefs about AIBO's physical sentience in two ways—through forced choice questions and through explanatory responses.

Forced choice questions (physical sentience). The forced choice questions were three items: an item about AIBO's capacity to feel physiological sensations ("If you tickle AIBO, can AIBO feel it?"), an item regarding AIBO's ability to feel physical pain ("If AIBO fell on the ground, could AIBO get hurt?"), and a categorization item in which we asked whether AIBO was more similar to an agent (a real dog) or an artifact (a stuffed dog). For a full list, see Table 1.

Explanatory responses (physical sentience). Because explanatory responses may be richer and more diagnostic of children's thinking than forced choice responses (see Wellman, 2011), we also assessed physical sentience using explanatory responses. For each question in the previous paragraph, children were asked to explain their choice (e.g., "Why/why not?"), which resulted in three explanatory responses. In addition, each child was prompted for a *behavioral cause explanation*: AIBO always performed one unexpected behavior (not getting a tennis ball after the experimenter rolled it past AIBO).[2] The experimenter narrated the behavior ("Uh oh! AIBO isn't getting the tennis ball!") and prompted the child for an explanation ("Why did that happen?"). Thus, children provided four total explanatory answers regarding their beliefs about physical sentience; coding is described in "Coding."

Emotional/Psychological Sentience

We additionally assessed AIBO's emotional/psychological sentience through forced choice and explanatory responses.

Forced choice questions (emotional/psychological sentience). We asked two items: one regarding AIBO's ability to feel emotional pain ("If someone was mean to AIBO, could AIBO get upset?") and another regarding his response to neglect ("Is it okay or not okay to leave AIBO in a closet for a week?").

Explanatory responses (emotional/psychological sentience). After each item, children were asked to provide an explanatory response ("Why/why not?"), resulting in two explanatory responses. The coding for these is described in "Coding."

Table 1. Full Battery of Questions Asked (Forward Presentation Order of Items in Parentheses).

Response Category	*Items Asked*	*Coding Scheme*
Physical sentience—forced choice responses	(2a) *Tactile response*: If you tickle AIBO, can AIBO feel it?	1 = yes 0 = no
	(5a) *Ability to feel physical pain*: If AIBO fell on the ground, could AIBO get hurt?	1 = yes 0 = no
	(10a) *Categorization (agent vs. nonagent)*: Look, here's a real dog, and here's a stuffed dog. Which one is AIBO more like?	1 = real dog 0 = stuffed dog
Physical sentience—explanatory responses	(1) *Behavioral cause explanation*: Uh oh! AIBO isn't getting the tennis ball. Why did that happen? (2b) *Tactile response*: […] Why/why not? (5b) *Ability to feel physical pain*: […] Why/why not? (10b) *Categorization (agent vs. nonagent)*: […] Why/why not?	*Physiological states*: "He'll get hungry" *Mechanical properties*: "He'll run out of batteries"
Emotional/psychological sentience—forced choice responses	(6b) *Ability to feel emotional pain*: If someone was mean to AIBO, could AIBO get upset?	1 = yes 0 = no
	(7a) *Consequences of neglect*: One person I talked to said they left AIBO in the closet for a week when they went on vacation. What about you, do you think it's okay or not okay to leave AIBO in the closet for a week if you go on vacation?	1 = not okay 0 = okay
Emotional/psychological sentience—explanatory responses	(6b) *Ability to feel emotional pain*: […] Why/why not? (7b) *Consequences of neglect*: […] Why/why not?	*Desire/emotions*: "He doesn't like that," "He'll be sad" *Physiological states*: "He'll get hungry" *Mechanical properties*: "He'll run out of batteries"
Moral standing—forced choice responses	(4a) *Physical harm*: Someone else I played with hit AIBO because AIBO didn't play with the ball. What about you, do you think it's okay or not okay to hit AIBO because AIBO didn't play with the ball? What if your [camp] counselor said it was okay to hit AIBO. Then do you think it would be okay, or not okay?	1 = not okay even if counselor says it's okay 0 = otherwise
	(8a) *Emotional harm*: Someone else I played with yelled at AIBO because AIBO didn't sit down. What about you, do you think it's okay or not okay to yell at AIBO because he didn't sit down? What if your [camp] counselor said it was okay to hit AIBO. Then do you think it would be okay, or not okay?	1 = not okay even if counselor says it's okay 0 = otherwise
Moral standing—explanatory responses	(4b) *Physical harm*: […] Why/why not? (8b) *Emotional harm*: […] Why/why not?	*Moral concern*: "It wouldn't be nice," "AIBO would cry" *External consequences*: "You'd get in trouble," "He'll break"
Prosocial behavior	(3) *Noncostly behavior*: I have a bouncy ball. You can put it here so that my friend Paul/Mary [gender matched to child] can play with it later, or you can put it here so that AIBO can play with it later. Which one do you want to give the ball to?	1 = give to AIBO 0 = give to Paul/Mary
	(9) *Costly behavior*: Here's a sticker and this sticker is just for you. You can either keep it for yourself, or you can give it to AIBO. What do you want to do?	1 = give to AIBO 0 = keep for self

Table 2. Proportions of Children Ascribing Sentience/Sharing for Each Forced Choice and Behavioral Item Across Conditions.

Dimension	*Item Type*	*Autonomous*	*Controlled*
Physical sentience	Categorization	63%	54%
	Ability to feel physical pain	90%	80%
	Tactile response	68%	62%
Emotional/psychological sentience	Ability to feel emotional pain	85%	74%
	Consequences of neglect	88%	74%
Moral standing	Wrongness of physical harm	83%	85%
	Wrongness of emotional harm	73%	72%
Prosocial behavior	Costly behavior	45%	41%
	Noncostly behavior	85%	70%

Note. Numbers represent the proportion of children who gave an answer or behavior consistent with AIBO having sentience or moral standing. For further details on the items and coding scheme, see Table 1.

Moral Standing

Next we assessed children's beliefs about moral standing both through forced choice and explanatory responses.

Forced choice questions (moral standing). We asked children whether the permissibility of two behaviors—yelling at and hitting AIBO—was independent of authority mandates (see Smetana, 1983; Turiel, 1983). Because testing was conducted at a summer camp, we used a camp counselor as the authority figure ("Is it okay to hit AIBO if your counselor says it's okay?").

Explanatory responses (moral standing). After each item, children were asked to explain their choice ("Why is it okay/not okay to hit AIBO?"; see "Coding").

Prosocial Behavior

Finally, we gave children the ability to engage in two prosocial behaviors toward AIBO—a *costly behavior* (giving AIBO a sticker or keeping it for themselves) and a *noncostly behavior* (playing with AIBO and a rubber bouncy ball vs. leaving the ball for another child).

Question Presentation Order

Prior to data collection, all questions were shuffled to create a random ordering, with two rules: (a) Explanatory questions had to follow their corresponding forced choice question; and (b) all sessions began with the behavioral cause explanation question ("AIBO isn't getting the tennis ball. Why did that happen?"), as this question needed to be asked during the interaction with AIBO. For each child, the random ordering was then presented in either a backward or forward manner (counterbalanced). The forward ordering is shown in Table 1.

Coding

The coding for each category of question is described here and summarized in Table 1.

Physical Sentience—Forced Choice

For each item, answers were coded 1 if the child's answer was consistent with AIBO having a sentient capacity (e.g., AIBO can feel being tickled, AIBO is more like a real dog than a stuffed dog) and 0 otherwise (see Table 1). Answers were averaged such that each child received a physical sentience forced choice score.

Physical Sentience—Explanatory Responses

Each explanation was coded as either (a) references to physiological states (e.g., "He's tired," "He might starve or poop") or (b) references to mechanical properties (e.g., "He has batteries," "He can't feel anything because he's just a robot," "He's made of metal"). Answers for each category type were summed across the four explanatory questions such that each child received two scores indicating the number of times the child provided each explanation type across the four questions: references to mechanical properties score (0–4) and references to physiological states score (0–4). Uncategorizable/other responses were not further analyzed.

Emotional/Psychological Sentience—Forced Choice

As with physical sentience, answers were coded 1 if the child's answer endorsed AIBO as having emotional or psychological sentience (e.g., AIBO is capable of being upset) and 0 otherwise. Answers were averaged such that each child received an emotional/psychological sentience forced choice score.

Emotional/Psychological Sentience—Explanatory Responses

As with physical sentience, children's explanations were coded into the aforementioned categories: (a) references to physiological states and (b) references to mechanical properties. In addition, we coded for (c) references to desires and emotions (e.g., "AIBO doesn't like that," "He'll get so sad"). Answers for each category type were summed across the two explanatory questions such that each child received three scores indicating the number of times he or she provided each explanation type across the two emotional/psychological sentience items: references to mechanical properties score (0–2), references to physiological properties (0–2), and references to desires and emotions (0–2). Uncategorizable/other responses were not further analyzed.

Moral Standing—Forced Choice

Each answer was coded 1 if the child indicated that it was not okay to harm AIBO even if the authority figure stated it was okay and 0 otherwise. Answers were averaged such that each child received a moral standing forced choice score.

Moral Standing—Explanatory Responses

Each answer was coded into one of the following categories: (a) references to moral concern (indications of moral rules: "It wouldn't be fair," and references to harm: "It would make AIBO sad"), (b) references to external consequences (e.g., "You would get in trouble," "It might break"), or (c) uncategorizable responses. Answers for each category type were summed across the two explanatory questions such that each child received two scores indicating the number of times the child provided each explanation type across the two categorizable questions: references to moral concern score (0–2) and references to external consequences score (0–2). Uncategorizable responses were not further analyzed.

Prosocial Behavior

Behaviors were given a score of 1 if the child engaged in the prosocial behavior toward AIBO (e.g., gave AIBO the sticker or ball) and 0 if he or she did not. Behaviors were summed such that each child received a prosocial behavior score (0–2).

Intercoder Reliability

Forced choice coding and behavioral responses (via listening to children's verbalized choice from audio) was done by one of us; a condition-blind research assistant then coded 25% of the responses (interrater reliability = 99%; $\kappa = .97$, $p < .001$).

Explanatory responses were transcribed for further coding. One of us then categorized all explanations. A condition-blind research assistant then separately categorized all of the explanations (interrater reliability = 83%; $\kappa = .79$, $p < .001$).

Results

Data Analysis Plan

To investigate whether condition or age impacted children's reactions to the robot, we ran a Condition (autonomous/controlled) × Age Group (5-year-olds/7-year-olds) analysis of variance on each of the dependent variables. For explanatory assessments, a repeated measures analysis of variance was used with explanation type entered as a within-subjects dependent variable.

We also explored for potential effects of gender and experience with real dogs. For each model, we added the factors gender (male/female) and experience with real dogs (yes/no) separately and removed each one if it was nonsignificant ($p > .05$). Unless otherwise stated, no effects for these variables were found. Significant condition effects were followed up via planned t tests comparing scores between conditions. For all reported follow-up tests, we adjusted p values using a sequential

Bonferroni correction for multiple comparisons. Raw proportions for forced choice and behavioral items are shown in Table 2.

Finally, we explored potential coherence between forced choice responses and explanation types. For each of our verbal dependent variables (physical sentience, emotional/psychological sentience, and moral standing), we conducted correlations between children's forced choice responses (e.g., physical sentience score) and their explanation type scores (e.g., references to physiological states score). We adjusted for multiple correlational analyses within the same dependent variable by using a sequential Bonferroni correction. For analyses looking at each item separately, please see the Supplemental Material.

Physical Sentience

Our first question was whether children would be more likely to ascribe physical sentience to the robot dog when it was moving in an autonomous manner than when it was controlled.

Forced Choice Responses

There were no significant effects of condition or age or Condition × Age Group interaction for children's physical sentience scores (all *p*s > .05).

Explanatory Responses

There was a significant main effect of explanation type and age group: explanation type, $F(1, 75) = 24.27$, $p < .001$, $\eta_p^2 = 0.25$; age group, $F(1, 75) = 6.56$, $p < .05$, $\eta_p^2 = 0.08$. In addition, there was a significant Explanation Type × Condition interaction and an Explanation Type × Age Group interaction: Explanation Type × Condition, $F(1, 75) = 12.61$, $p < .01$, $\eta_p^2 = 0.11$; Explanation Type × Age Group, $F(1, 75) = 6.85$, $p < .05$, $\eta_p^2 = 0.06$. Thus, the frequency of each explanation type differed across conditions and age groups.

Of critical interest was whether explanation types differed between conditions. To explore the Explanation Type × Condition interaction, we conducted planned *t* tests to assess differences in explanation type scores across conditions (see Figure 2). Children in the autonomous condition had higher references to physiological states scores than those in the controlled condition, $t(77) = 3.41$, $p < .01$, $d = 0.78$. In contrast, children in the controlled condition had higher references to mechanical properties scores, $t(78) = -2.06$, $p < .05$, $d = 0.47$.

Children's explanations cohered well with their forced choice responses. Higher physical sentience scores were positively associated with explanations that made references to physiological states

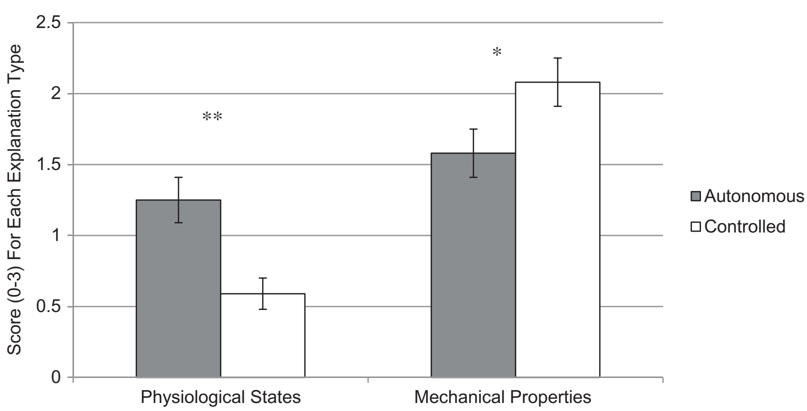

Figure 2. Means (bars represent standard errors) for the number of explanation types across conditions for physical sentience explanatory responses. Asterisks indicate significant differences between conditions. *$p < .05$. **$p < .01$.

and negatively associated with explanations that made references to mechanical properties: physiological states, $r(79) = .48$, $p < .001$; mechanical properties, $r(79) = -.51$, $p < .001$. Therefore, children who stated that AIBO had physical sentience also followed those statements with references to AIBO's physiological states. In contrast, children who stated that AIBO did *not* have physical sentience tended to follow those statements with references to AIBO's mechanical properties.

As indicated through children's explanatory responses, children ascribed higher physical sentience through ascribing basic physiological properties when the robot was autonomous.

Emotional/Psychological Sentience

Our next question was whether children would be more likely to ascribe emotional and psychological sentience to the robot dog when it was moving autonomously than when it was controlled.

Forced Choice Responses

There was a significant main effect of condition, $F(1, 75) = 4.40$, $p < .05$, $\eta_p^2 = 0.06$, and no other significant effects (all $ps > .25$). Children in the autonomous condition ascribed higher emotional sentience to AIBO than those in the controlled condition.

Explanatory Responses

There was a significant main effect of explanation type and age group: explanation type, $F(2, 150) = 17.06$, $p < .001$, $\eta_p^2 = 0.19$; age group, $F(1, 75) = 6.17$, $p < .05$, $\eta_p^2 = 0.08$. In addition, there was a significant Explanation Type × Condition interaction, $F(2, 150) = 3.99$, $p < .05$, $\eta_p^2 = 0.05$.

Follow-up planned *t* tests revealed that children in the autonomous condition had higher references to desires and emotion states scores than those in the controlled condition, $t(77) = 2.50$, $p < .05$, $d = 0.57$ (see Figure 3). The proportion of children who referenced mechanical properties or physiological properties did not differ across conditions ($p > .15$).

Children's explanations again cohered well with their forced choice responses. Higher emotional and psychological sentience forced choice scores were positively associated with explanations that made references to physiological states, positively associated with explanations that made references to desires and emotions, and negatively associated with explanations that made references to mechanical properties: physiological states, $r(79) = .21$, $p = .05$; desires and emotions, $r(79) = .42$, $p < .001$; mechanical properties, $r(79) = -.72$, $p < .001$. Therefore, children who ascribed higher

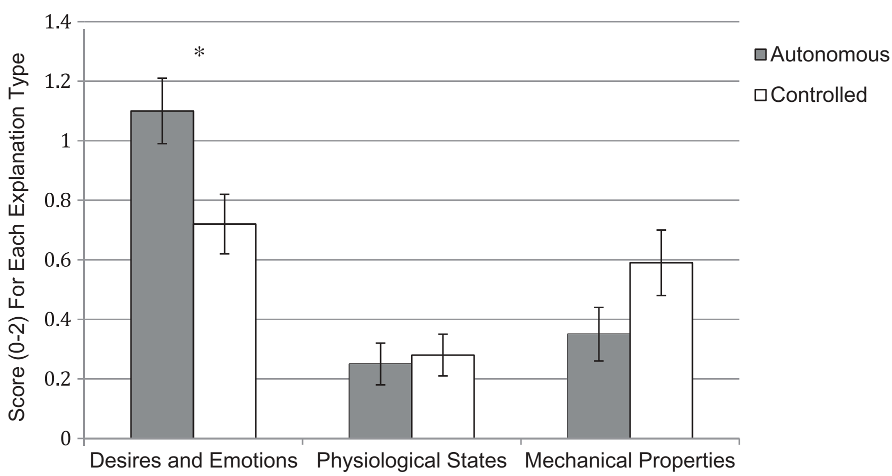

Figure 3. Means (bars represent standard errors) for the number of explanation types across conditions for emotional and psychological sentience explanatory responses. Asterisks indicate significant differences between conditions. *$p < .05$.

emotional and psychological sentience also tended to reference AIBO's desires, emotions, and physiological states but not its mechanical properties.

Overall, children's forced choice and explanatory responses indicated that children in the autonomous condition were more likely to ascribe emotional and psychological sentience to AIBO than those in the controlled condition.

Moral Standing

Our next question concerned whether children would be more likely to endorse moral standing for an autonomously moving robot dog than a controlled robot dog.

Forced Choice Responses

There were no significant effects of condition or age or Condition × Age interaction for children's moral regard scores (all *p*s > .05). A follow-up analysis revealed that this was because of a ceiling effect—the majority of children (56 of 78) indicated that they believed that neither behavior (yelling or hitting) was appropriate toward AIBO even if an authority figure stated it was okay.

Explanatory Responses

There was a significant Condition × Explanation Type interaction, $F(1, 75) = 10.81$, $p < .01$, $\eta_p^2 = 0.13$, and no other significant effects (all *p*s > .05).

Once again, of critical interest was whether explanation types differed between conditions. Planned *t* tests were conducted to assess differences in explanation type scores across conditions (see Figure 4). Children in the autonomous condition had higher references to moral concern scores and lower references to external consequences than those in the controlled condition: moral concern, $t(77) = 3.80$, $p < .01$, $d = 0.87$; external consequences, $t(77) = 2.05$, $p < .05$, $d = 0.47$.

Again, children's forced choice responses cohered with their explanation types. Higher moral standing forced choice scores were negatively associated with explanations that made references to external consequences and positively associated with references to moral concern: external consequences, $r(78) = -.47$, $p < .001$; moral concern, $r(78) = .51$, $p < .001$. Therefore, children who were more likely to answer that it was not okay to harm AIBO were also more likely to explain this with references to moral concern for AIBO.

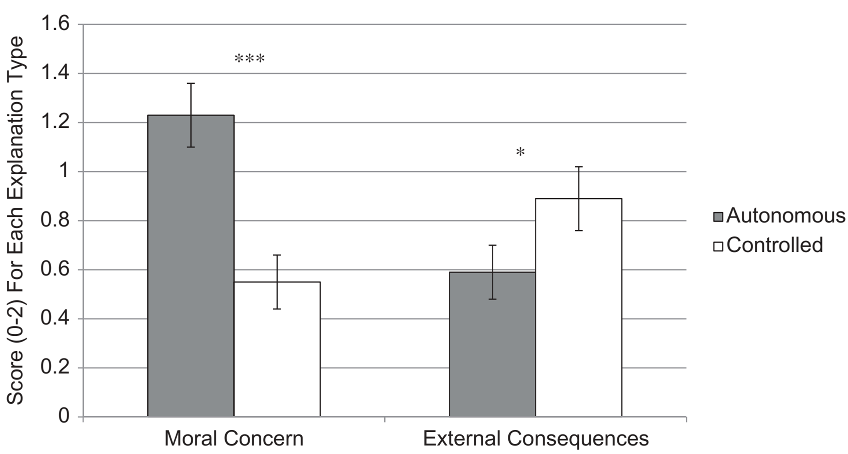

Figure 4. Means (bars represent standard errors) for the number of explanation types across conditions for moral standing explanatory responses. Asterisks indicate significant differences between conditions. *$p < .05$. ***$p < .001$.

Overall, although most children in both conditions indicated that it was not okay to harm the robot, children in the autonomous condition were more likely to cite moral reasons for their decisions than those in the controlled condition.

Prosocial Behavior

Finally, our last question was whether children would be more likely to behave prosocially toward an autonomous robot than a controlled one.

There was a significant Condition × Experience With Real Dogs interaction in prosocial behavior scores, $F(1, 71) = 7.09$, $p < .01$, $\eta_p^2 = 0.09$, and no other significant effects (all *ps* > .05; see Figure 5). Follow-up comparisons showed that children who owned a real dog showed differentiation in their prosocial behavior between the autonomous and controlled conditions. That is, children in the autonomous condition had higher prosocial behavior scores, $t(34) = 3.27$, $p < .01$, $d = 1.15$. In contrast, children who did *not* own a real dog showed no condition differences ($p > .50$). Therefore, experience with real dogs coupled with autonomous movement caused increased prosocial behavior toward a robotic dog.

Discussion

Across a large battery of questions including forced choice responses, explanatory responses, and behavioral responses, we show that children showed higher moral regard for a robot that displayed autonomous, uncontrolled movement. Our findings join literature suggesting that people's perceptions of and attributions to others depend on their beliefs in their autonomy (Gray et al., 2007; Somanader et al., 2011; Sytsma & Machery, 2012). We extend this work by showing that cues to autonomous movement also impact beliefs about physical and emotional sentience, moral standing, and prosociality and that these links appear relatively early in development. This finding is important given the recent work on interactive social robots and virtual characters (Aguilar & Taylor, 2015; Bernstein & Crowley, 2008; Scaife & Van Duuren, 1995) as well as work suggesting that even infants make social evaluations about nonhuman others (e.g., shapes with eyes; Hamlin, Wynn, & Bloom, 2007). Based on our findings, we suggest that the manner in which nonhuman others are presented to young children fundamentally impacts children's naïve biological theories of them.

Across every single question asked, we found that children's explanatory responses were much more diagnostic of their reasoning than forced choice measures. Children self-articulated beliefs that

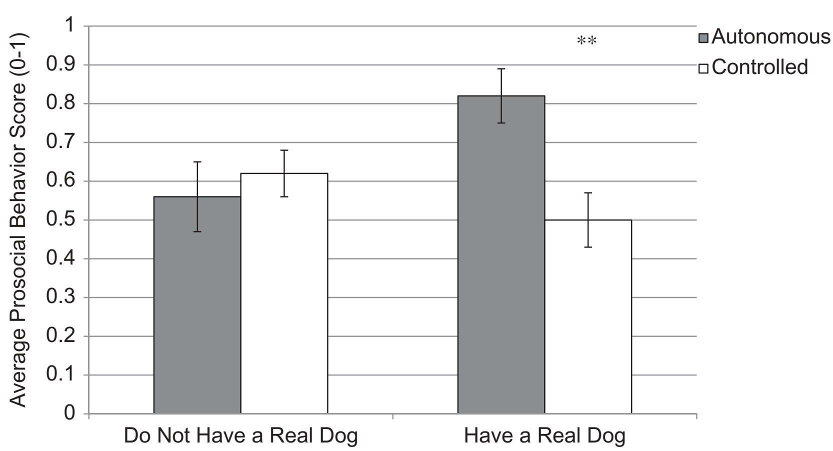

Figure 5. Means (bars represent standard errors) across condition type and real dog experience groups for prosocial behavior score. Asterisks indicate significant differences between conditions. **$p < .01$.

autonomously moving robots possessed emotions and desires and stated that moral rules applied to autonomously moving robots. In contrast, children who saw robots moving in a controlled manner were likely to reference internal mechanical properties (e.g., batteries) when reasoning about why the robot could or could not get hurt and reference external consequences (getting in trouble) when reasoning about why one could/should not harm the robot. Children's explanations were also particularly coherent with their forced choice responses—for example, children who referenced the robot as having desires and emotions were also more likely to answer that the robot could get upset. We also found that even when forced choice responses did not show variation across conditions, explanatory responses did. For example, we found that children rigidly endorsed harming AIBO as being wrong independent of authority mandates, a finding that is well aligned with prior work (Turiel, 1983). At the same time, children's explanatory responses showed that their reasoning as to *why* it was wrong to harm AIBO was consistent with reasoning about AIBO's moral standing *only* when AIBO was moving autonomously. In contrast, children who saw AIBO moving in a controlled manner stated that it was wrong to harm the robot but referenced external consequences to themselves (e.g., "I still might get in trouble") or damaging the personal property of human agents (e.g., "It's someone else's stuff"). These latter explanatory responses suggest a denial of the robot's moral standing rather than a confirmation of it. Taken together, our results highlight the importance of moving beyond forced choice questions to tap into children's reasoning and suggest a role for explanatory responses in revealing children's naïve biological and moral theories.

We also found an important link between apparent autonomy and children's moral regard and prosocial behavior. This result suggests that children conceptualize autonomously moving robots not only as agents (cf. Somanader et al., 2011) but as beings that are worthy of moral regard. Who and what children determine to be worthy of their moral regard is an important philosophical and psychological question, and one possibility may be that autonomous movement helps trigger children's moral regard for robotic others. This possibility is consistent with findings suggesting that young children from urban Western cultures show naïve anthropomorphic thinking around 5 years of age (Carey, 1985; Herrmann, Waxman, & Medin, 2010). In the context of our present study, it is possible that without the presence of a remote control, children also anthropomorphize robotic others—the high proportion of children who ascribed desires, emotions, and physiological states to an autonomously moving robot dog suggests that this might be the case. Another possibility is that an apparent *lack* of autonomy may help children selectively target their behavior to exclude nonautonomous others (e.g., controlled robots). This finding is consistent with research showing that young children selectively target their behaviors toward in-group members (Dunham, Baron, & Carey, 2011; Engelmann, Over, Herrmann, & Tomasello, 2013) and may expect others to do the same (Burns & Sommerville, 2014; DeJesus, Rhodes, & Kinzler, 2014; Weller & Lagattuta, 2012). Additional work may also investigate whether self-generated movement serves as a cue for in-group status, moral obligation, or potential to reciprocate.

In our work we provided several cues to autonomy: a lack of external cause (i.e., no remote control) and experimenter testimony (i.e., "I'm making AIBO move"). Prior work has found that the presence of a remote control may be sufficient in causing preschoolers' differentiation between autonomous and nonautonomous others with respect to ascription of biological and representational properties (Somanader et al., 2011), and further work may disambiguate which specific features of autonomy cause moral regard.

Children showed increased prosocial behavior toward an autonomous robot only when they had previous experience with a real dog. Prior work (see Inagaki & Hatano, 2002) has found that the experience of raising goldfish caused children to ascribe biological properties to the goldfish (e.g., having a heart). Here, children's experience with an agent (a pet dog) caused greater prosocial behavior toward autonomous robots, suggesting that experience with animal agents may cause a greater obligation toward the artifacts designed to mimic them. Given that emotional and physical sentience items were unaffected by prior experience, we propose that this effect may be specific to children's early experiences with pet ownership and the obligations that follow rather than children's exposure to animal agents more generally.

We also found that even a 5-min interaction with an autonomous robot affected children's categorizations and evaluations of the robot. An important question remains regarding the impact of extended experience with robot dogs on children's conceptualization of them. One possibility is that extended experience with robot dogs would allow children to understand their inner workings (and therefore their similarity to artifacts). This possibility is supported by the fact that adults, who presumably have more experience with robots than do children, do not ascribe sentience to robots (e.g., Jipson & Gelman, 2007). Another possibility, however, is that experience with robots would help children reorganize their conceptualization of them—as children are more exposed to robotic others, they may begin to view these robots as distinct from both artifacts and agents.

These findings are interesting to consider with respect to children's beliefs about causal reasoning (see Sobel, Yoachim, Gopnik, Meltzoff, & Blumenthal, 2007). Here we find that although the robot in both conditions displayed the same exact perceptual properties and surface movements, children nonetheless paid attention to the causal source of the robot's movement. We propose that rather than paying attention to surface properties of technology, children are able to reason about causal movements and essences. In fact, our results showed that children tended to ascribe internal characteristics such as physiological states in the autonomous condition and external circumstances (e.g., "Maybe it's broken") in the controlled condition. Thus, children's causal thinking may importantly interact with their prosocial behavior and moral regard toward others.

Finally, we wish to outline several ways in which our findings may be of use to early childhood educators. First, recent work has shown the potential of interactive social robots to impact children's learning (for examples, see Han, Jo, Jones, & Jo, 2008; Kanda, Hirano, Eaton, & Ishiguro, 2004; Scassellati, Admoni, & Mataric, 2012). It is important to note that our work suggests that the manner in which robots are introduced impacts the way in which children regard the robots—either as beings worthy of moral regard or as social-technological tools outside of one's moral circle. Given our reported findings, it may be important to study how these divergent ways of conceptualizing technologies impact children's abilities to learn from them. One possibility is that either presentation may be fruitful depending on the learning content the robots aim to transmit. For example, practitioners using robots to help improve children's social-emotional development (e.g., Stanton, Kahn, Severson, Ruckert, & Gill, 2008) may want to present robots as autonomous beings. At the same time, researchers focusing on using robots as purely cognitive educational tools may wish to present robots as human-controlled technologies that may be exploited for their educational purposes. Second, as robots become ubiquitous in children's lives, it is important to consider how they may shape children's moral development more broadly. Growing up in households with seemingly autonomous social robots may scaffold children's abilities to care for autonomous beings or, conversely, help children more quickly understand that technologies lay outside of their moral circle. Further work may probe into how long-term experiences with social robots impact children's regard for them. Finally, although our work focuses on studying a binary way of introducing social robots (autonomous vs. controlled), it is likely that robots are frequently introduced along a continuum between fully controlled and fully autonomous beings in naturalistic settings. Therefore, it will be important for future work to study the manner in which adults within the child's social context—namely, parents, educators, and those who develop robots—spontaneously introduce robots and interactive technologies. Prior work has found that people flexibly switch between conceiving of robots as autonomous agents on the one hand and artifacts on the other (Crick & Scasselatti, 2010; Kahn et al., 2006, 2012), and it is possible that adult–child conversation surrounding robots reflects that domain confusion. Overall, we believe that our work paves the way to consider the emerging role of nonhuman others in people's daily lives—whether in educational settings, child care centers, or their own homes—as well as how presenting such technologies to young children impacts their understanding of them.

Notes

1. The grouping of all of our items into the reported categories was done both conceptually (on the basis of prior work) as well as empirically (through a factor analysis, reported in our Supplemental Material).
2. For this question, we took advantage of the fact that the robot dog was not programmed to fetch tennis balls.

Acknowledgments

We would like to thank L. Gary for assistance with data collection and coding, J. Sommerville for comments on an earlier draft, and P. Kahn for kindly lending equipment.

ORCID

Nadia Chernyak http://orcid.org/0000-0003-3061-0523

References

Aguilar, N. R., & Taylor, M. (2015). Children's concepts of social affordances of a virtual dog and a stuffed dog. *Cognitive Development*, *34*, 16–27. doi:10.1016/j.cogdev.2014.12.004

Aknin, L. B., Hamlin, J. K., & Dunn, E. W. (2012). Giving leads to happiness in young children. *PLoS One*, *7*, e39211.

Beier, J. S., & Carey, S. (2014). Contingency is not enough: Social context guides third-party attributions of intentional agency. *Developmental Psychology*, *50*, 889–902. doi:10.1037/a0034171

Bernstein, D., & Crowley, K. (2008). Searching for signs of intelligent life: An investigation of young children's beliefs about robot intelligence. *Journal of the Learning Sciences*, *17*, 225–247. doi:10.1080/10508400801986116

Burns, M. P., & Sommerville, J. A. (2014). "I pick you": The impact of fairness and race on infants' selection of social partners. *Frontiers in Developmental Psychology*, *5*, 93. doi:10.3389/fpsyg.2014.00093

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.

Chernyak, N., & Kushnir, T. (2013). Giving preschoolers choice increases sharing behavior. *Psychological Science*, *24*, 1971–1979. doi:10.1177/0956797613482335

Crick, C., & Scasselatti, B. (2010). Controlling a robot with intention derived from motion. *Cognitive Science*, *2*, 114–126.

DeJesus, J. M., Rhodes, M., & Kinzler, K. D. (2014). Evaluations versus expectations: Children's divergent beliefs about resource distribution. *Cognitive Science*, *38*, 178–193. doi:10.1111/cogs.2014.38.issue-1

Dunham, Y., Baron, A. S., & Carey, S. (2011). Consequences of "minimal" group affiliations in children. *Child Development*, *82*, 793–811. doi:10.1111/cdev.2011.82.issue-3

Engelmann, J. M., Over, H., Herrmann, E., & Tomasello, M. (2013). Young children care more about their reputation with ingroup members and potential reciprocators. *Developmental Science*, *16*, 952–958.

Gao, T., McCarthy, G., & Scholl, B. J. (2010). The wolfpack effect: Perception of animacy irresistibly influences interactive behavior. *Psychological Science*, *21*, 1845–1853. doi:10.1177/0956797610388814

Gelman, S. A., & Gottfried, G. M. (1996). Children's causal explanations of animate and inanimate motion. *Child Development*, *67*, 1970–1987.

Gergely, G., & Csibra, G. (2003). Teleological reasoning in infancy: The naïve theory of rational action. *Trends in Cognitive Sciences*, *7*, 287–292. doi:10.1016/S1364-6613(03)00128-1

Gray, H. M., Gray, K., & Wegner, D. M. (2007, February 2). Dimensions of mind perception. *Science*, *315*, 619. doi:10.1126/science.1134475

Hamlin, J. K., Wynn, K., & Bloom, P. (2007, November 22). Social evaluation by preverbal infants. *Nature*, *450*, 557–559. doi:10.1038/nature06288

Han, J. H., Jo, M. H., Jones, V., & Jo, J. H. (2008). Comparative study on the educational use of home robots for children. *Journal of Information Processing Systems*, *4*, 159–168. doi:10.3745/JIPS.2008.4.4.159

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *American Journal of Psychology*, *57*, 243–259. doi:10.2307/1416950

Herrmann, P., Waxman, S. R., & Medin, D. L. (2010). Anthropocentrism is not the first step in children's reasoning about the natural world. *Proceedings of the National Academy of Sciences, USA*, *107*, 9979–9984. doi:10.1073/pnas.1004440107

Inagaki, K., & Hatano, G. (2002). *Young children's naïve thinking about the biological world*. New York, NY: Psychology Press.

Jipson, J. L., & Gelman, S. A. (2007). Robots and rodents: Children's inferences about living and nonliving kinds. *Child Development*, *78*, 1675–1688. doi:10.1111/cdev.2007.78.issue-6

Johnson, S., Slaughter, V., & Carey, S. (1998). Whose gaze will infants follow? The elicitation of gaze-following in 12-month-olds. *Developmental Science*, *1*, 233–238. doi:10.1111/desc.1998.1.issue-2

Kahn, P. H., Jr., Friedman, B., Perez-Granados, D. N., & Freier, N. G. (2006). Robotic pets in the lives of preschool children. *Interaction Studies*, *7*, 405–436. doi:10.1075/is.7.3.13kah

Kahn, P. H., Jr., Gary, H. E., & Shen, S. (2013). Children's social relationships with current and near-future robots. *Child Development Perspectives*, *7*, 32–37. doi:10.1111/cdep.12011

Kahn, P. H., Kanda, T., Ishiguro, H., Freier, N. G., Severson, R. L., Gill, B. T., … Shen, S. (2012). "Robovie, you'll have to go into the closet now": Children's social and moral relationships with a humanoid robot. *Developmental Psychology*, *48*, 303–314. doi:10.1037/a0027033

Kanda, T., Hirano, T., Eaton, D., & Ishiguro, H. (2004). Interactive robots as social partners and peer tutors for children: A field trial. *Human-Computer Interaction*, *19*, 61–84.

Saxe, R., Tenenbaum, J. B., & Carey, S. (2005). Secret agents inferences about hidden causes by 10-and 12-month-old infants. *Psychological Science*, *16*, 995–1001. doi:10.1111/j.1467-9280.2005.01649.x

Scaife, M., & Van Duuren, M. (1995). Do computers have brains? What children believe about intelligent artifacts. *British Journal of Developmental Psychology*, *13*, 367–377. doi:10.1111/bjdp.1995.13.issue-4

Scassellati, B., Admoni, H., & Mataric, M. (2012). Robots for use in autism research. *Annual Review of Biomedical Engineering*, *14*, 275–294. doi:10.1146/annurev-bioeng-071811-150036

Smetana, J. G. (1983). Social-cognitive development: domain distinctions and coordinations. *Developmental Review*, *3*, 131–147.

Smith, C. E., Blake, P. R., & Harris, P. L. (2013). I should but I won't: Why young children endorse norms of fair sharing but do not follow them. *PLoS ONE*, *8*, e59510. doi:10.1371/journal.pone.0059510

Sobel, D. M., Yoachim, C. M., Gopnik, A., Meltzoff, A. N., & Blumenthal, E. J. (2007). The blicket within: Preschoolers' inferences about insides and causes. *Journal of Cognition and Development*, *8*, 159–182. doi:10.1080/15248370701202356

Somanader, M. C., Saylor, M. M., & Levin, D. T. (2011). Remote control and children's understanding of robots. *Journal of Experimental Child Psychology*, *109*, 239–247. doi:10.1016/j.jecp.2011.01.005

Sommerville, J. A., Hildebrand, E. A., & Crane, C. C. (2008). Experience matters: The impact of doing versus watching on infants' subsequent perception of tool-use events. *Developmental Psychology*, *44*, 1249–1256. doi:10.1037/a0012296

Stanton, C. M., Kahn, P. H., Jr., Severson, R. L., Ruckert, J. H., & Gill, B. T. (2008). Robotic animals might aid in the social development of children with autism. *Human-Robot Interaction*, 271–278.

Sytsma, J., & Machery, E. (2012). The two sources of moral standing. *Review of Philosophy and Psychology*, *3*, 303–324. doi:10.1007/s13164-012-0102-7

Turiel, E. (1983). *The development of social knowledge: Morality and convention*. Cambridge, UK: Cambridge University Press.

Vaish, A., Missana, M., & Tomasello, M. (2011). Three-year-old children intervene in third-party moral transgressions. *British Journal of Developmental Psychology*, *29*(1), 124–130.

Weller, D., & Lagattuta, K. (2012). Helping the in-group feels better: Children's judgments and emotion attributions in response to prosocial dilemmas. *Child Development*, *84*, 253–268. doi:10.1111/j.1467-8624.2012.01837.x

Wellman, H. M. (2011). Reinvigorating explanations for the study of early cognitive development. *Child Development Perspectives*, *5*, 33–38. doi:10.1111/j.1750-8606.2010.00154.x

Woodward, A. L., Sommerville, J. A., Gerson, S., Henderson, A. M., & Buresh, J. (2009). The emergence of intention attribution in infancy. *Psychology of Learning and Motivation*, *51*, 187–222.