Children's cognitive and behavioral reactions to an autonomous versus controlled social robot dog

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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 towards it. We asked five and seven-year-old children to interact with a robot dog that was either described 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 also more likely to behave prosocially towards the autonomous robot than those who did not. **Policy and Practice:** 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, while presenting robots as human-controlled may help promote robots as purely cognitive educational tools.

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"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 No.5 had displayed emotional sophistication proving it worthy of moral regard, while others felt that No.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 our moral regard is a critical cognitive achievement. In 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 life-like ways, some of which include the ability to move around autonomously (Kahn, Gary, & Shen, 2013). Due to their relative historical novelty, the manner in which such technologies are presented to young children is understudied. As such, 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 five-minute interaction with an either autonomously moving or controlled robot impacted children's beliefs in the robot as a sentient being, endorsement of the robot as having moral standing, and prosocial behavior towards the robot.

Our research question is motivated by two concerns. First, our work aimed to understand the developing link between our moral cognition and our 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., see Gergely & Csibra, 2003; Heider & Simmel, 1944; Saxe, Tenenbaum, & Carey, 2005; Sommerville, Hildebrand, & Crane, 2008; Woodward, Sommerville, Gerson, Henderson, & Buresch, 2009; see also Gao, McCarthy, & Scholl, 2010 for a demonstration with adults). In fact, many studies using infant cognition arguably employ 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 our moral regard (Gray et al., 2007; Jipson & Gelman, 2007). Therefore, a second 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 et al., 2012; Kahn, Friedman, Perez-Granados, & Freier, 2006). Such work has largely focused on children's ability to form relationships with, and thus conceive of robots 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 in 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 non-living, but nonetheless be unable to inhibit their moral regard for them. After all, children have been shown to be prosocial even towards animal puppets (e.g., Aknin, Hamlin, & Dunn, 2012; Chernyak & Kushnir, 2013; Vaish, Missana, & Tomasello, 2011). Finally, a third 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-aged 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, 2008). Here, we use 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: Five-year-olds and seven-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., possess 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: (1) Emotional Sentience, (2) Physical

Sentience, (3) Moral Standing, and (4) Prosocial Behavior. Dimensions (1), (2), and (3) were assessed through both forced-choice and explanatory responses; dimension (4) was assessed through behavioral responses.

Method

Participants

Participants were eighty children (Forty 5-year-olds; *M* = 5.50, *SD* = .30; and forty 7-year-olds; *M* = 7.35, *SD* = .36; 50% female) recruited from a summer camp in Colorado. Participants were of predominantly European-American, middle-class background. Children were tested individually in a quiet corner. One child was excluded from final analyses due to having 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 our 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 thus presumably entirely novel to 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-minute interaction with a robot dog, AIBO (Figure 1). The robotic dog is not commercially available, thus rendering it unlikely that children had any previous interaction with it. Children were first shown the robot and informed that they will be playing with it. All children then watched AIBO engage in a series of pre-programmed 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.

Manipulation

Children were randomly assigned to one of two conditions. Forty-one 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 child and narrated AIBO's behavior in a manner consistent with controlled movement ("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: (1) Emotional Sentience, (2) Physical Sentience, (3) Moral Standing, and (4) Prosocial Behavior. Questions were adapted from prior work assessing children's conceptualization of robotic others (Jipson & Gelman, 2007; Kahn, Friedman, Perez-Granados, & Freier, 2006; Kahn et al., 2012), moral reasoning (Smetana, 1983), and prosocial behavior (Chernyak & Kushnir, 2013). The questions and coding scheme are described below 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.

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[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 Supplementary Materials).

Forced Choice Questions (Physical Sentience). The *forced choice questions* were 3 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 above, children were asked to explain their choice (e.g., "Why/why not?"), thus resulting in 3 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 4 total explanatory answers regarding their beliefs about physical sentience; coding is described in the Coding section below.

Emotional/Psychological Sentience

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

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 OK or not OK to leave AIBO in a closet for a week?").

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[2] For this question, we took advantage of the fact that the robot dog was not programmed to fetch tennis balls.

Explanatory Responses (Emotional/Psychological Sentience). After each item, children were asked to provide an explanatory response ("Why/why not?") resulting in 2 explanatory responses. The coding for these is described in the Coding section below.

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 OK to hit AIBO if your counselor says it's OK?")

Explanatory Responses (Moral Standing). After each item, children were asked to explain their choice ("Why is it OK/not OK to hit AIBO?"); see Coding section.

Prosocial Behavior

Finally, we gave children the ability to engage in two prosocial behaviors towards 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?"), since this question needed to be asked during the interaction with AIBO. For each child, the random ordering was then presented in either a backwards or forwards manner (counterbalanced). The forward ordering is shown in Table 1.

Coding

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

Physical Sentience – Forced Choice. For each item, answers were coded as 1 if the child's answer was consistent with AIBO having a sentient capacity (e.g., AIBO could 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) reference 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 4 explanatory questions such that each child received 2 scores indicating the number of times the child provided each explanation type across the 4 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 as 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 above-referenced categories: (a) references to physiological states and (b) references to mechanical properties. Additionally, we coded for (c) reference 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 2 explanatory questions such that each child received 3 scores indicating the number of times s/he 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 as 1 if the child indicated that it was not OK to harm AIBO even if the authority figure stated it was OK, 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 2 explanatory questions such that each child received three 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 towards AIBO (e.g., gave AIBO the sticker or ball), and “0” if s/he 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 the authors; a condition-blind research assistant then coded 25% of the responses (Inter-rater reliability = 99%; Kappa = .97, $p < .001$).

Explanatory responses were transcribed for further coding; One of the authors then categorized all explanations. A condition-blind research assistant then separately categorized all of the explanations (Inter-rater 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) x Age Group (five-year-olds/seven-year-olds) ANOVA on each of the dependent variables. For explanatory assessments, a repeated-measures ANOVA 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 non-significant ($p > .05$). 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 Bonferonni correction for multiple comparisons.

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 adjust for multiple correlational analyses within the same dependent variable using a sequential Bonferonni correction. For analyses looking at each item separately, please see our Supplementary Analyses.

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, age, or condition x age interaction for children's moral regard scores, all *p*'s > .05.

Explanatory Responses. There was a significant main effect of Explanation Type, $F(1, 75) = 24.27$, $p < .001$, $\eta_{partial}^2 = 0.25$, and Age Group, $F(1,75) = 6.56$, $p < 0.05$, $\eta_{partial}^2 = 0.08$. Additionally, there was a significant Explanation Type x Condition interaction, $F(1, 75) = 12.61$, $p < .01$, $\eta_{partial}^2 = 0.11$, and an Explanation Type x Type x Age Group interaction, $F(1, 75) = 6.85$, $p < 0.05$, $\eta_{partial}^2 = 0.06$. 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 x Condition interaction, planned *t*-tests were conducted to assess differences in explanation type scores across conditions (Figure 2). Children in the autonomous condition had higher References to Physiological States Scores than those in the controlled condition, $t(77) = 3.41$, $p < .01$, $d = .78$. In contrast, children in the controlled condition had higher References to Mechanical Properties Scores, $t(78) = -2.06$, $p < .05$, $d = .47$.

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, $r(79) = .48$, $p < .001$, and negatively associated with explanations that made References to 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 Type, $F(1,75) = 4.40$, $p < 0.05$, $\eta_{partial}^2 = 0.06$, and no other significant effects (all *p*'s > .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, $F(2, 150) = 17.06$, $p < .001$, $\eta_{partial}^2 = 0.19$, and Age Group, $F(1,75) = 6.17$, $p < 0.05$, $\eta_{partial}^2 = 0.08$. Additionally, there was a significant Explanation Type x Condition interaction, $F(2, 150) = 3.99$, $p < .05$, $\eta_{partial}^2 = 0.05$.

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, $t(77) = 2.50$, $p < .05$, $d = .57$. 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, $r(79) = .21$, $p = .05$, positively associated with explanations that made references to Desires and Emotions, $r(79) = .42$, $p < .001$, and negatively associated with explanations that made References to Mechanical Properties, $r(79) = -.72$, $p < .001$. Therefore, children who ascribed higher emotional and psychological sentience also tended to reference AIBO's desires, emotions, and physiological states, but not his/her 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, age, or condition x age interaction for children's moral regard scores, all *p*'s > .05. A follow-up analysis revealed that this was due to a ceiling effect – the majority of children (56 of 78) indicated that they believed that neither behavior (yelling or hitting) was appropriate towards AIBO even if an authority figure stated it was okay.

Explanatory Responses. There was a significant Condition x Explanation Type interaction, $F(1, 75) = 10.81$, $p < .01$, $\eta_{partial}^2 = 0.13$, 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 (Figure 4). Children in the autonomous condition had higher References to Moral Concern Scores than those in the controlled condition, $t(77) = 3.80$, $p < .01$, $d = .87$, and lower References to External Consequences, $t(77) = 2.05$, $p < .05$, $d = .47$

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, $r(78) = -.47$, $p < .001$, and positively associated with References to Moral Concern, $r(78) = 0.51$, $p < .001$. Therefore, children who were more likely to answer that it was not OK to harm AIBO were also more likely to explain this with references to moral concern for AIBO.

Overall, although most children in both conditions indicated that it was not OK 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 towards an autonomous robot than a controlled one.

There was a significant Condition Type x Experience with Real Dogs interaction in Prosocial Behavior scores, $F(1, 71) = 7.09$, $p < .01$, $\eta_{partial}^2 = 0.09$, and no other significant effects (all p's > .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 towards 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 our perceptions of and attributions to others depend on our 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 our 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, 2007; Scaife & Van Duuren, 1995) as well as work suggesting that even infants make social evaluations about non-human others (e.g., shapes with eyes; Hamlin, Wynn, & Bloom, 2008). Based on our findings, we suggest that the manner in which non-human 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 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 couldn't 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 robots' 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 (c.f., 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 this might the be the case. Another possibility is that an apparent *lack* of autonomy may help children selectively target their behavior to exclude non-autonomous others (e.g., controlled robots). This finding is consistent with research showing that young children selectively target their behaviors selectively towards in-group members (Dunham et al., 2011; Engelmann, Over, Hermann, & 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 non-autonomous 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 towards 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 a greater prosocial behavior towards autonomous robots, suggesting that experience with animal agents may cause a greater obligation towards 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 five-minute 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 its inner workings (and therefore its 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 the 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 towards 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 (see Han, Jo, Jones, & Jo, 2008; Kanda, Hirano, Eaton, & Ishiguro, 2004; Scassellati, Admoni, & Mataric, 2012 for examples). Importantly, our work suggests that the manner in which robots are introduced impacts the way 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 impacts 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 socio-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, while our work focuses on studying a binary way of introducing social robots (autonomous versus 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 we flexibly switch between conceiving of robots as autonomous agents on the one hand, and artifacts on the other (Crick & Scasselatti, 2010; Kahn et al., 2012; Kahn et al., 2006), and it is possible that adult-child conversation surrounding robots reflects that domain confusion. Overall, we believe our work paves the way to consider the emerging role of non-human others in our daily lives – whether in educational settings, childcare centers, or in our own homes – as well as how presenting such technologies to young children impacts their understanding of them.

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Table 1. Full Battery of Questions Asked (forwards 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. Non-Agent): 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?	Physiological States: "he'll get hungry" Mechanical Properties: "he'll run out of batteries"
	(2b) Tactile Response: […] Why/Why not?	
	(5b) Ability to Feel Physical Pain: […] Why/Why not?	
	(10b) Categorization (Agent vs. Non-Agent): [….] Why/Why not?	
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 OK or not OK to leave AIBO in the closet for a week if you go on vacation?	1 = not OK 0 = OK
Emotional / Psychological Sentience – Explanatory Responses	(6b) Ability to Feel Emotional Pain: […] 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"
	(7b) Consequences of Neglect: [….] Why/Why not?	
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 OK or not OK to hit AIBO because AIBO didn't play with the ball? What if your [camp] counselor said it was OK to hit AIBO. Then do you think it would be OK, or not OK?	1 = not OK even if counselor says it's OK 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 OK or not OK to yell at AIBO because he didn't sit down? What if your [camp] counselor said it was OK to hit AIBO. Then do you think it would be OK, or not OK?	1 = not OK even if counselor says it's OK 0 = otherwise
Moral Standing – Explanatory Responses	(4b) Physical Harm: [….] Why/Why not?	Moral Concern: "it wouldn't be nice"; "AIBO would cry" External Consequences: "you'd get in trouble"; "he'll break"
	(8b) Emotional Harm: […] Why/Why not?	
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

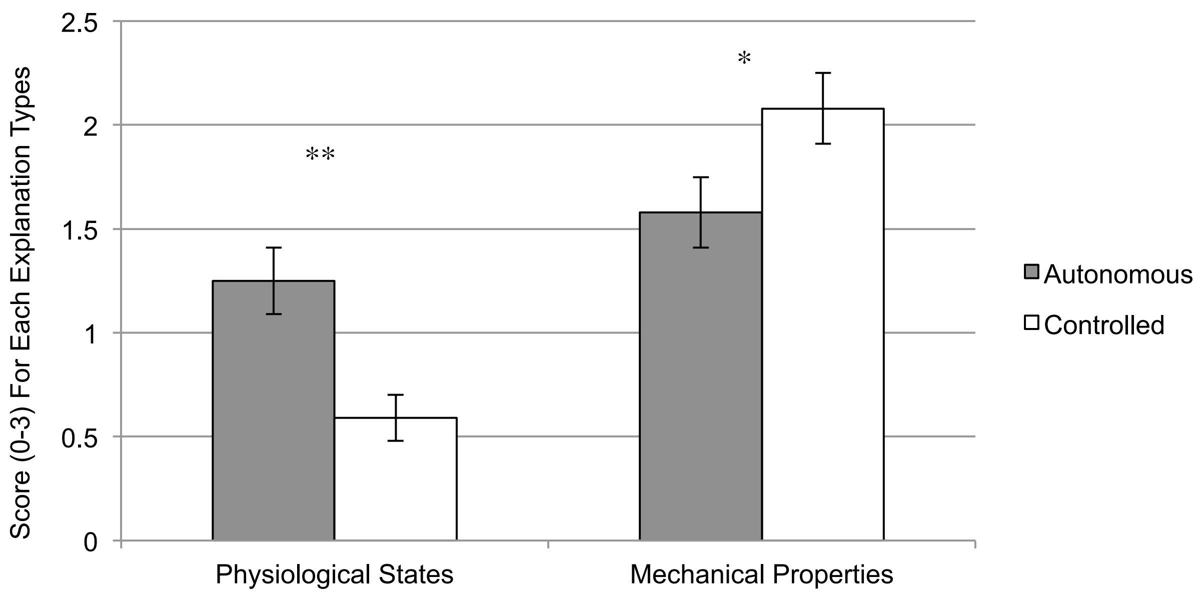
Table 2. Proportions of Children Ascribing Sentience/Sharing for Each Forced Choice and Behavioral Item Across Conditions

	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%
	Non-Costly 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.

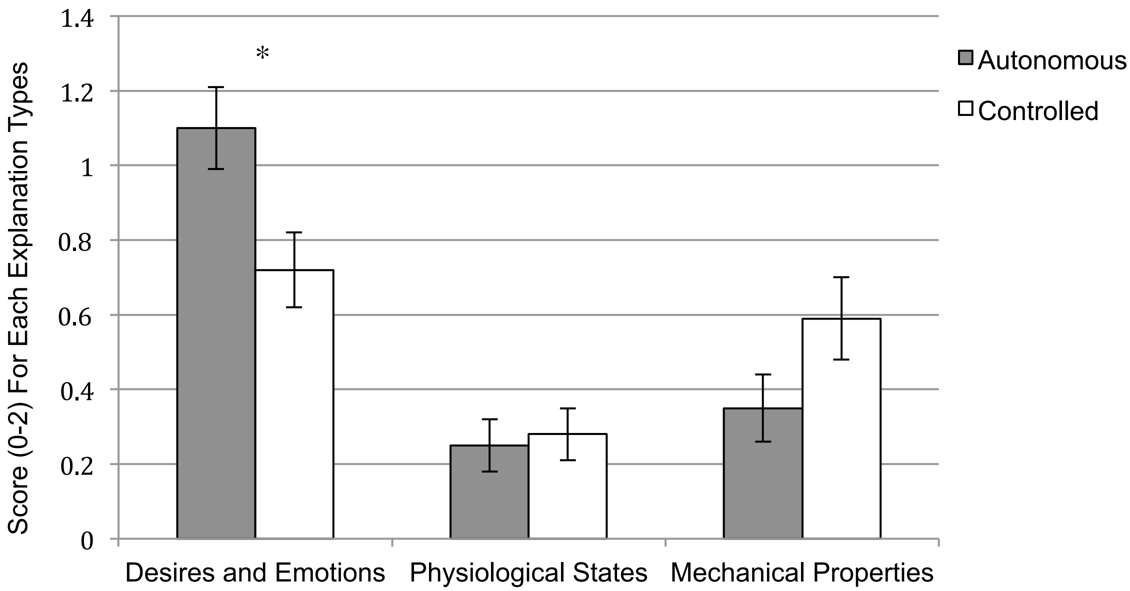
Figure 1. The robot dog AIBO tracks a pink ball

Figure 2. Means (bars represent standard errors) for Number of Explanation Types Across Conditions for the Physical Sentience Explanatory Responses



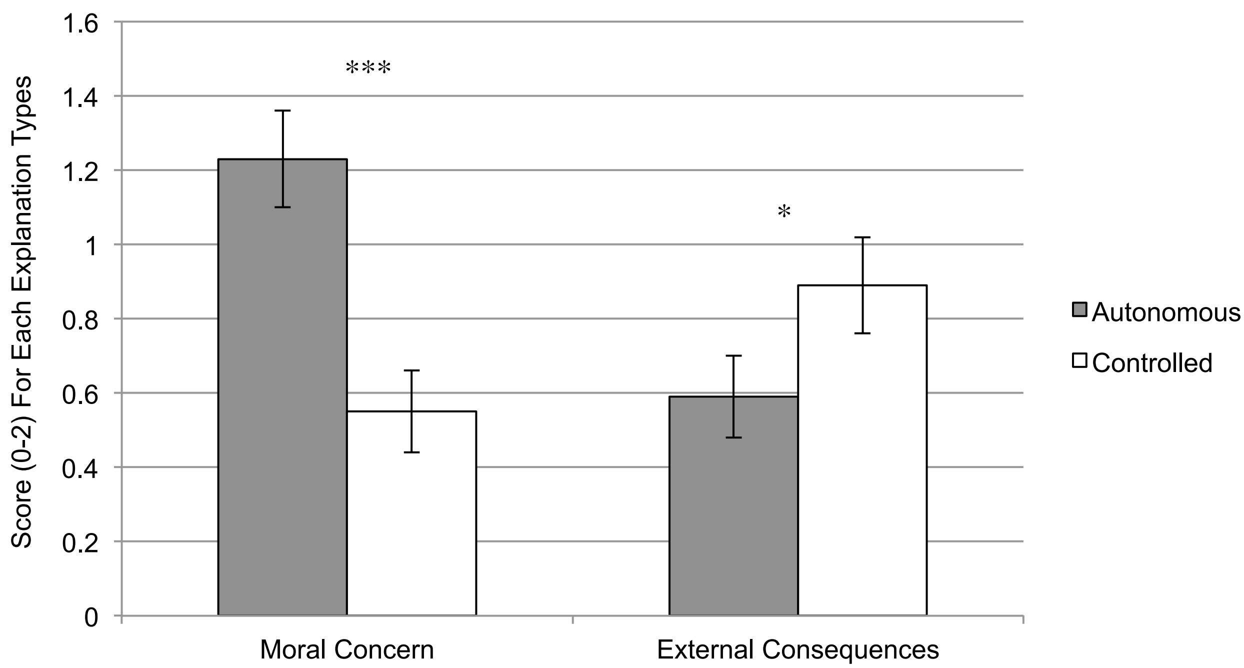
Asterisks indicate significant differences between conditions (*, $p < .05$; **, $p < .01$).

Figure 3. Means (bars represent standard errors) for Number of Explanation Types Across Conditions for the Emotional and Psychological Sentience Explanatory Responses



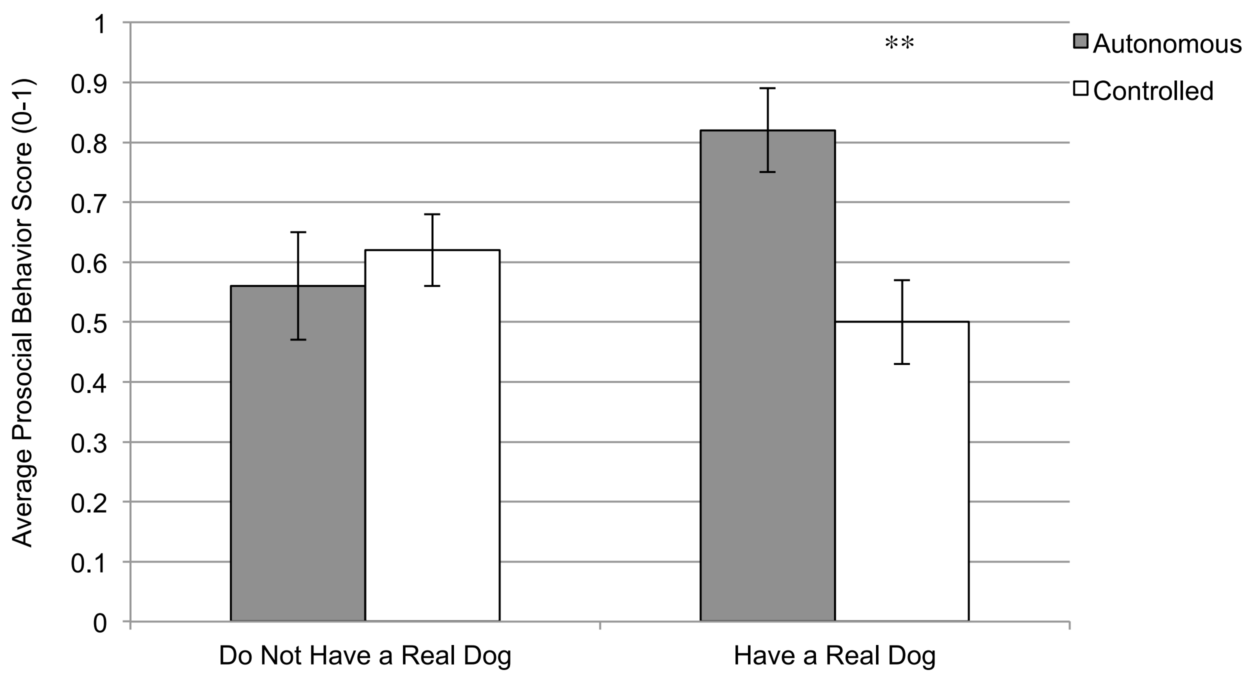
Asterisks indicate significant differences between conditions (*, $p < .05$).

Figure 4. Means (bars represent standard errors) for Number of Explanation Types Across Conditions for the Moral Standing Explanatory Responses



Asterisks indicate significant differences between conditions (*, $p < .05$; ***, $p < .001$)

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 (**, $p < .01$)