Journal of Experimental Child Psychology 109 (2011) 239–247

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Brief Report

Remote control and children's understanding of robots

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ARTICLE INFO

Article history:
Received 19 July 2010
Revised 13 January 2011
Available online 23 February 2011

Keywords:
Cognitive development
Preschoolers
Categorization
Robots
Theory of mind
Representation

ABSTRACT

Children use goal-directed motion to classify agents as living things from early in infancy. In the current study, we asked whether preschoolers are flexible in their application of this criterion by introducing them to robots that engaged in goal-directed motion. In one case the robot appeared to move fully autonomously, and in the other case it was controlled by a remote. We found that 4- and 5-year-olds attributed fewer living thing properties to the robot after seeing it controlled by a remote, suggesting that they are flexible in their application of the goal-directed motion criterion in the face of conflicting evidence of living thing status. Children can flexibly incorporate internal causes for an agent's behavior to enrich their understanding of novel agents.

Introduction

From infancy, the presence of autonomous fluid motion that is produced in the service of a goal is used as a cue to living thing status (Rakison & Poulin-Dubois, 2001). Infants use features of goal-directed motion to predict the future behavior of agents. For example, they expect objects engaging in goal-directed motion to change direction spontaneously, remain in place after an external force (Luo, Kaufman, & Baillargeon, 2009), and act on other agents at a distance (Schlottman & Ray, 2010). The application of this criterion persists until preschool. Opfer and Siegler (2004) revealed that telling 5-year-olds that plants can engage in goal-directed motion led them to infer that plants were living things (see also Carey, 1985; Hatano et al., 1993; Inagaki & Hatano, 1996). Preschoolers also infer that a novel entity is a living thing if it engages in goal-directed motion rather than aimless motion (Opfer, 2002; see also Gelman & Gottfried, 1996; Massey & Gelman, 1988). However, questions remain about how flexibly the criterion is applied. One possibility is that when children see an object engage in goal-directed

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doi:10.1016/j.jecp.2011.01.005

motion, they apply features of living things to it without further consideration of the plausibility of the attributes. On the other hand, children may be more flexible. If children are given a cause for the self-directed motion that is not consistent with living thing status, they may be less likely to attribute features of a living thing to the entity. We investigated these possibilities in the current study.

Previous research suggests that children may be flexible in their categorization of novel entities. In particular, even though infants distinguish robots from living things (e.g., Arita, Hiraki, Kanda, & Ishiguro, 2005; Hofer, Hauf, & Aschersleben, 2005; Poulin-Dubois, Lepage, & Ferland, 1996), the behavior of robots influences infants' classifications. For example, infants were surprised to see a person "talk" to a robot unless they had been given prior experience with the robot engaging in contingent interaction (Arita et al., 2005), and toddlers imitated the actions of a humanoid robot only after the entity made "eye contact" with them (Itakura et al., 2008; see also Levin, Saylor, Killingsworth, Gordon, & Kawamura, 2011). In addition, although preschoolers see entities such as robots as being globally different from living things, they sometimes attribute properties of living things to robots (e.g., Jipson & Gelman, 2007; Melson et al., 2005; Mikropoulos, Misailidi, & Bonoti, 2003; Okita, Schwartz, Shibata, & Tokuda, 2007; Saylor, Somanader, Levin, & Kawamura, 2010).

In the current study, we asked whether this flexibility in classification is also applied to the putative goal-directed motion of robots. To do so, we manipulated the *source* of the robot's behavior. This information has been previously investigated by applying an external force to an entity, for example, by pushing it (Gelman & Gottfried, 1996). In these cases, the causal mechanism is relatively transparent. In contrast, in the current study, there was a more indirect cause of motion.

In the current study, 4- and 5-year-olds were exposed to one of two versions of a single robot. In both cases, the robot engaged in the same series of goal-directed motions, but in one group the robot was controlled by a remote. Children were asked to indicate whether the robot had diagnostic features of living things (*representational* and *biological* properties) and machines (*mechanical* properties). We included three types of features to probe the specificity of changes in children's attributions. If the source of an apparently goal-directed motion affects children's attributions, they may show a reduction in their tendency to attribute features of living things to the agents (but attributions of mechanical properties might not be affected). For comparison purposes, children were also asked about whether familiar entities possessed these features. We used 4- and 5-year-olds in the study because they have shown stable inferences about robots but are still developing their understanding of living and nonliving things.

Method

Participants

A total of 66 children participated: 34 4-year-olds (mean age = 56 months, 16 girls and 18 boys) and 32 5-year-olds (mean age = 67 months, 18 girls and 14 boys). Participants were recruited from state birth records and were primarily from upper middle-class households. An additional 11 children were omitted due to equipment error (6), experimenter error (3), noncompliance (1), or sibling interference (1).

Design

A between-subjects design was used. Children were assigned to one of two conditions: *autonomous* (17 4-year-olds, 6 girls and 11 boys, mean age = 55 months, and 16 5-year-olds, 8 girls and 8 boys, mean age = 67 months) and *controlled* (17 4-year-olds, 10 girls and 7 boys, mean age = 57 months, and 16 5-year-olds, 10 girls and 6 boys, mean age = 67 months). There were no differences in the mean age across condition for either age group ($ts \leqslant 1.69$, $ps \geqslant .10$). The same robot engaging in the same goal-directed motions was used in both conditions. The only difference was whether children were given information about what made the robot move. In the autonomous condition, the robot moved with no evidence of a human controller; thus, it appeared to engage in self-directed motion. In the controlled condition, the robot moved only after an experimenter pressed buttons on a remote control to create the illusion that the experimenter was controlling the robot.

Materials and equipment

Children were shown three pretest items (a couch, a rug, and a video camera) and three target items (the robot, a 13-inch television set [TV], and a person). All entities were present during the testing session.

The robot was constructed using a VEX robotics design system that was covered with a silver box with plastic tubing attached. The robot had a mix of anthropomorphic and nonanthropomorphic features. It had a head and eyes and was referred to with a proper name and personal pronouns, but it also had wheels and was made of metal.

Two buttons were constructed to serve as the "remote control" for the robot in the controlled condition. The color of the buttons (red and green) matched the colors of two small rubber balls that the robot hit (see Fig. 1).

A small hand puppet was used to ask the children test questions. Two Mini-DV cameras mounted on tripods were used to record each session.

Children were asked 14 questions about each target item: 4 representational items ("Can _____ see you/think/remember me if I left/count to five?"), 3 biological items ("Does _____ get hungry/have a mommy? Is _____ alive?"), and 7 mechanical items ("Did someone put _____ together? Can a grown-up take _____ apart? Can _____ break? Does _____ have metal/wires inside? Can you turn

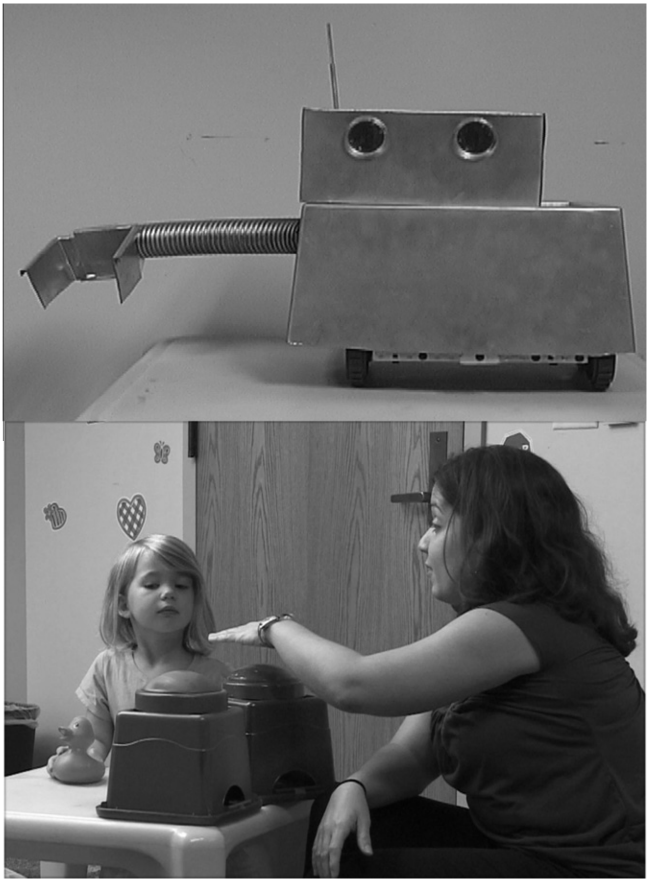

Fig. 1. Robot used in both conditions and remote used in the controlled condition.

_____ on? Is _____ a machine?"). The name of the entity being asked about was inserted into the blank (i.e., Experimenter 2's name, Sparky, or TV).

Procedure

Two experimenters were involved. Experimenter 1 (E1) interacted with children and asked them the questions during the test phase. E2 surreptitiously controlled the robot from an adjacent room, served as the target for the person questions, and recorded children's responses to test questions. During the initial part of the experiment, children remained unaware of E2; she hid in the adjacent room before their arrival.

E1 and children sat at a table across the room from the robot on the other side. The robot was positioned in between the two colored balls.

The study was divided into two phases: *robot exposure* and *test*.

Robot exposure phase

The autonomous condition began with children being introduced to the robot ("This robot's name is Sparky!"). E1 then said, "Sparky is going to hit one of the balls. I wonder which one he's going to hit." This was the cue for E2, who watched the session with the aid of a two-way mirror, to move the robot. The robot oriented toward one of the balls, moved toward the ball, hit it one time, and then moved backward to its original position. E1 then said, "Let's watch Sparky do it again!" and the robot repeated the procedure for the other ball. E1 narrated the actions by saying, "Sparky is going to hit the ball!" and "Sparky hit the ball!"

The controlled condition followed the same script and sequence of events except that after telling children the name of the robot, E1 introduced them to the remote by saying, "When I press the red button, Sparky will hit the red ball. When I press the green button, Sparky will hit the green ball." E1 then repeated this information while pointing at the button and ball each time. E1 then said, "Sparky's going to hit the ball!" before pressing one of the buttons. E2 then made the robot move. The order in which the robot hit the balls was roughly counterbalanced.

Test phase

After the robot hit both balls, children were introduced to a puppet that was used to ask the test questions. E1 then asked children a series of preliminary questions to help them warm up to the task: "Is that a couch? Is that couch blue? Is that a rug? Is that rug on the ceiling? Is that a camera? Is that camera black?"

Children were then told that they would be asked about other things in the room but that E1 "needed someone else to play." E1 then asked E2 to come watch children play a game. E2 said, "I'll bring my work out here!" and then brought in a clipboard with the response sheet on it and sat next to the TV and robot.

Children were asked 14 test questions about the robot, the TV, and the person (E2). The order of the entity asked about was counterbalanced, and the question order was determined randomly (E1 shuffled the question cards before each entity).

Next, E1 asked children whether they thought that "Sparky moved by himself" or that "something else made him move." The 5-year-olds (28 of 32) were more likely to answer this question correctly than the 4-year-olds (18 of 34), $\chi^2 s(1) = 9.32$, $p = .002$, but there were no differences in children's tendency to answer the question correctly across conditions. To control for differences that might arise from variability in children's responses to this question, children's ability to answer the question correctly was entered as a covariate in the analyses below.

Coding

A "yes" response to the test questions was scored as 1, and any other response was scored as 0; the latter included children saying "no" and the rare instances (5.52% or 152 of 2772 questions) of children saying "I don't know" or not responding to a test question. Each child received three scores:

one for each of representational, biological, and mechanical questions. For ease of comparison, scores were analyzed as a proportion of “yes” responses.

Results

A 2 (Age: 4-year-olds or 5-year-olds) × 2 (Condition: autonomous or controlled) × 3 (Entity: person, TV, or robot) mixed multivariate analysis of covariance (MANCOVA) was run on children’s proportion of “yes” responses to representational, biological, and mechanical questions. Age and condition were between-participants variables, and entity was a within-participants variable. Whether children responded correctly to the source of the robot’s movement was entered as a covariate in the analysis. We use a parametric analysis strategy even though there was no variability in one of the cells in the analysis (the 5-year-olds did not attribute biological features to the TV) because the alternative was cumbersome and yielded the same pattern of findings. See Fig. 2 for data presented separately by age and condition.

The omnibus analysis revealed main effects of entity, Pillai’s $F(6, 56) = 50.23$, $p < .001$, $\eta_p^2 = .84$, age, Pillai’s $F(3, 59) = 3.53$, $p = .02$, $\eta_p^2 = .15$, and condition, Pillai’s $F(3, 59) = 3.89$, $p = .013$, $\eta_p^2 = .17$. There was also a significant interaction between entity and age, Pillai’s $F(6, 56) = 3.17$, $p = .010$, $\eta_p^2 = .25$.

Effects by condition

The condition effect was the result of children offering more “yes” responses in the autonomous condition than in the controlled condition. Univariate F tests clarified that this tendency was significant for representational properties, (autonomous $M = .55$, SD = .16, controlled $M = .45$, SD = .16), $F(1, 61) = 6.28$, $p = .02$, $\eta_p^2 = .09$, and biological properties (autonomous $M = .43$, SD = .16, controlled $M = .36$, SD = .14), $F(1, 61) = 4.10$, $p = .047$, $\eta_p^2 = .06$.

Because we had specific predictions about children’s treatment of the robot in the two conditions, we conducted planned comparisons using a simple effects analysis. There were no differences in children’s attributions to the robot in terms of biological properties (autonomous $M = .30$, SD = .34, controlled $M = .23$, SD = .30), $t(64) = 0.93$, $p = .36$, or mechanical properties (autonomous $M = .61$, SD = .29, controlled $M = .67$, SD = .30), $t(64) = 0.87$, $p = .38$. These findings held for each of the individual items except that children were more likely to say that the robot could be taken apart in the controlled condition than in the autonomous condition, $\chi^2(1) = 6.20$, $p = .01$. Of greatest interest, children were more likely to attribute representational properties to the robot in the autonomous condition ($M = .59$, SD = .29) than in the controlled condition ($M = .40$, SD = .37), $t(64) = 2.36$, $p = .02$. Analyses by individual items revealed that this effect was significant for the “remember” and “see” items, $\chi^2s(1) \geqslant 5.41$, $p \leqslant 02$.

Children did not show differences in their responding to the person and the TV across the two conditions with one exception: They were more likely to attribute biological properties to the TV in the autonomous condition ($M = .09$, SD = .17) than in the controlled condition ($M = .02$, SD = .08), $t(64) = 2.23$, $p = .03$. This effect was significant only for the “alive” item, $\chi^2s(1) = 5.12$, $p = .02$. It is not clear why this difference emerged. It seems unlikely to be the result of a response bias for attributing more biological properties in the autonomous condition because similar differences did not emerge for the robot or person.

Effects by entity and age

The main effect of entity was due to children being more likely to attribute representational properties ($M = .90$, SD = .18) and biological properties ($M = .87$, SD = .19) to the person than to the TV (representational $M = .11$, SD = .18, biological $M = .06$, SD = .14) and the robot (representational $M = .50$, SD = .35, biological $M = .27$, SD = .32), paired $ts(65) \geqslant 9.24$, $ps < .001$, and to children being less likely to attribute mechanical properties to the person ($M = .09$, SD = .15) than to the TV ($M = .61$, SD = .25) and the robot ($M = .64$, SD = .30), paired $ts(65) \geqslant 15.91$, $ps < .001$. These effects were significant for all 14 items, related samples McNemar change test, $\chi^2s(1) \geqslant 6.72$, $ps \leqslant .008$. In addition, children were

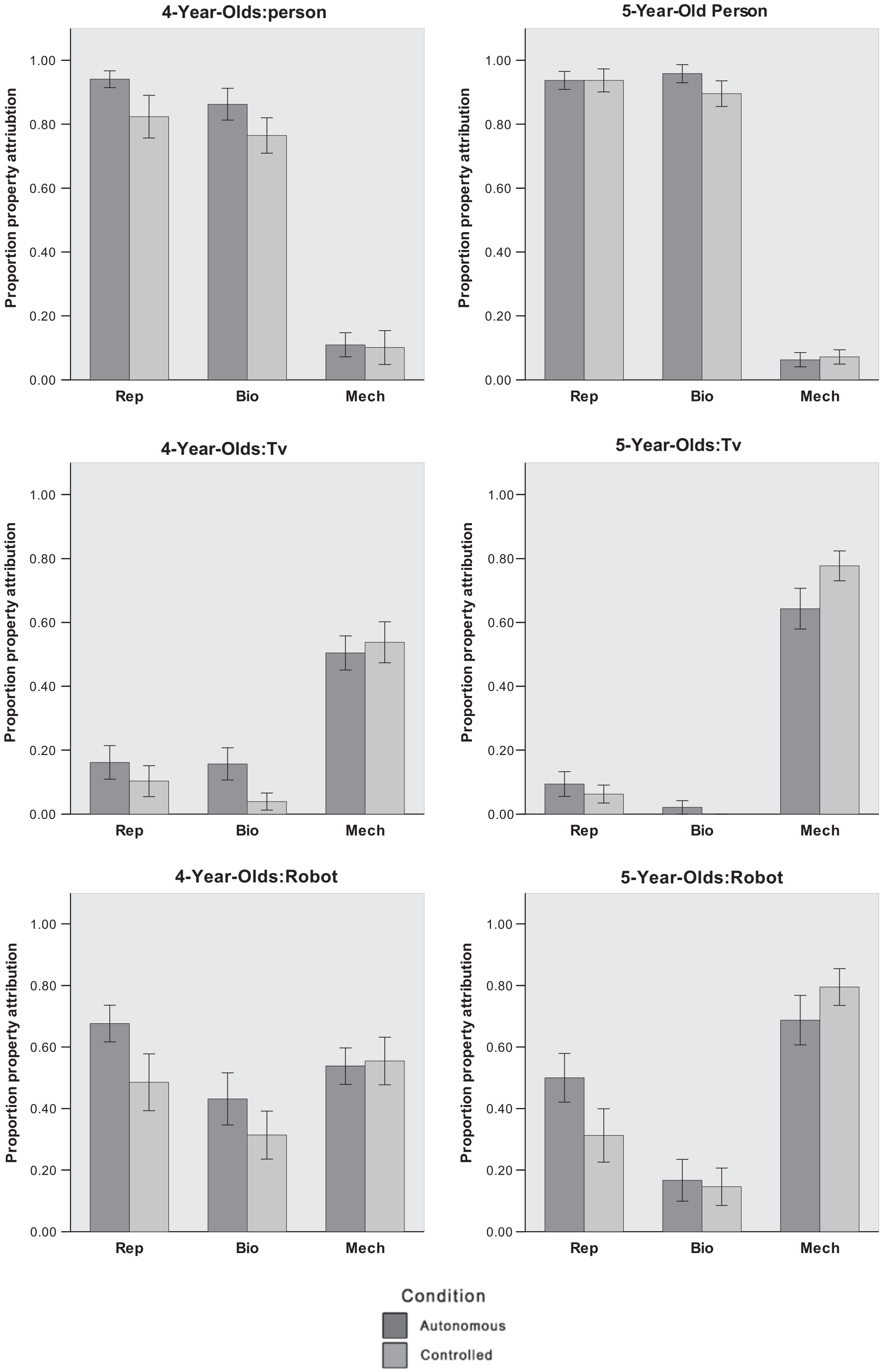

Fig. 2. Mean level of attribution of representational (Rep), biological (Bio), and mechanical (Mech) properties for the person, the TV, and the robot by age and condition.

more likely to attribute representational and biological properties to the robot than to the TV, paired $ts(65) \geqslant 6.02$, $ps < .001$. These differences were significant for each of the biological and representational items, McNemar change test, $\chi^2s(1) \geqslant 14.06$, $ps \leqslant .001$, except for the "have a mommy" item, McNemar change test, $\chi^2s(1) = 1.33$, $p = .25$.

There were no overall differences in children's tendency to attribute mechanical properties to the TV and the robot, $t(65) = 0.93$, $p = .36$. However, an analysis of individual items revealed variability in children's responding. They showed no significant differences in their attributions to the TV and the robot for the "break", "take apart", "wires", and "put together" items, McNemar change test, $\chi^2s(1) \leqslant 3.36$, $ps \geqslant .06$, but were more likely to endorse the robot for being made of metal, being a machine, and being put together, McNemar change test, $\chi^2s(1) \geqslant 4.05$, $ps \leqslant .04$, and more likely to endorse the TV for being turned on, McNemar change test, $\chi^2s(1) = 19.05$, $p < .001$. This variability in children's responding to mechanical questions is consistent with previous research on the topic (Freeman & Sera, 1996; Saylor et al., 2010).

The age effect was the result of the 4-year-olds endorsing more attributes than the 5-year-olds. Univariate *F* tests revealed that the Age × Entity interaction was significant only for biological properties, $F(2, 122) = 7.37$, $p = .001$, $\eta_p^2 = .11$, and mechanical properties, $F(2, 122) = 5.57$, $p < .005$, $\eta_p^2 = .08$. The 4-year-olds were more likely than the 5-year-olds to endorse biological properties for the TV and the robot, $ts(64) \geqslant 2.33$, $ps \leqslant .03$. The 5-year-olds showed a nonsignificant trend to be more likely to endorse biological properties for the person, $t(64) = 1.89$, $p = .06$. For mechanical properties, the 4-year-olds were less likely than the 5-year-olds to endorse such properties for the TV and the robot, $ts(64) \geqslant 2.05$, $ps \leqslant .04$, but showed no differences for endorsements for the person, $t(64) = 0.65$, $p = .52$.

Tests against chance

Children's proportion of "yes" responses was compared with a chance level of .50 using one-sample *t* tests. These analyses were conducted separately by age and condition. Unless mentioned otherwise, the findings were the same in both conditions and both ages. Responding was reliable and in the predicted direction for representational properties ($ts \geqslant 4.83$, $ps < .001$) and biological properties ($ts \geqslant 4.77$, $ps < .001$) for the TV and the person and for mechanical properties ($ts \geqslant 7.52$, $ps < .001$) for the person. The 5-year-olds were reliably above chance for the mechanical properties for the TV and the robot, $ts(15) \geqslant 2.24$, $ps \leqslant .04$, but the 4-year-olds were at chance, $ts(16) \leqslant 0.64$, $ps \geqslant .53$. Children's responding was below chance for biological properties for the robot ($ts \geqslant 2.38$, $ps \leqslant .03$) except for the 4-year-olds in the autonomous condition, where their responding did not differ from chance, $t(16) = 0.81$, $p = .43$. Responding to representational properties for the robot revealed sensitivity to the manipulation (decrease in representational features in the controlled condition); the 4-year-olds were at chance in the controlled condition, $t(16) = 0.16$, $p = .88$, and *above* chance in the autonomous condition, $t(16) = 2.95$, $p = .009$, and the 5-year-olds were *below* chance in the controlled condition, $t(15) = 2.16$, $p = .048$, and at chance in the autonomous condition, $t(15) = 0.00$, $p = 1.00$.

Discussion

The current findings indicate that children were flexible in how they applied features of living things to a goal-directed robot. Attributions of representational properties were reduced after they observed an experimenter controlling the robot relative to when no control was observed. In neither case did children attribute biological features to the entity (e.g., being alive), suggesting that they were sensitive to some of its physical features (e.g., being metal, having wheels).

This understanding of external causality is impressive. Using a remote as information about agency requires children to rely on an atypical link between action at a distance, which is a key characteristic of living things and an entity's status as a *nonliving* thing. It is likely that children relied on previous observations of remote controls when they considered our robot. However, this would require an inference of some depth because our remote looked nothing like a typical remote. In addition, the remote initiated a chain of actions (e.g., locating, moving to, and hitting a ball) that may be more complex than the actions initiated by a typical remote. Children successfully isolated the external cause for initiating a series of actions and used it to make the inference that the remote-initiated agent was less likely to see and remember. They were able to focus on this external cause in the face of a large number of other features, including having eyes and non-contact-initiated motion, all of which suggested that the agent should have these properties.

Children also differentiated among the TV, the person, and the robot in terms of a broad set of properties, attributing higher levels of representational and biological properties to the person than to the TV and the robot and attributing higher levels of representational and biologic properties to the robot than to the TV. The second finding is a departure from previous work showing that 4-year-olds tend to classify robots and familiar artifacts as the same kind of thing (Saylor et al., 2010) and may reflect children's sensitivity to our efforts to anthropomorphize the robot.

In sum, preschoolers are flexible about their attributions of goal-directed motion. They did not view the presence of goal-directed motion as sufficient to imbue an entity with features of living things if the origin of the motion was inconsistent with these attributions. One implication is that children make decisions about complex artifacts such as robots on a case-by-case basis and evaluate the properties of the entities based on the behavior in which the agents engage. This flexible and context-sensitive approach is appropriate because, on the one hand, such entities are artifacts constructed by humans, but on the other hand, they often carry out human-defined goals at least semiautonomously.

Acknowledgments

Portions of these data were presented at the 2007 Jean Piaget Society Conference in Amsterdam, The Netherlands, the 2007 Society for Research in Child Development Conference in Boston, MA, the 2007 Cognitive Science Conference in Nashville, TN, the 2008 International Conference on Person–Robot Interaction in Amsterdam, The Netherlands, and the 2009 Society for the Research on Child Development Conference in Denver, CO. Special thanks go to Catherine Blessing, Sarah Delisle, Alexandra Fortuna, Caroline Heaton, Stephen Killingsworth, Simon Lynn, Allison Milam, William Ober, Sarah Osei, Kathryn Otterbein, Anna Sangalis, Douglas Schatz, and Maria Vazquez for assistance with collecting and coding the data. This work was supported by grants from the National Science Foundation (0433653 and 0826701).

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