CHILDREN USE APPEARANCE AND ORIGIN OF MOTION TO CATEGORIZE ROBOTS

By

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CHAPTER I

INTRODUCTION

One challenge that children face when learning about new things is that the objects they encounter do not always clearly belong in one category or another. This is especially true of technological innovations like robotic toys and computers that are becoming an increasing presence in children's lives (Mikropoulos, Misailidi, & Bonoti, 2003; Okita & Schwartz, 2006). These entities may be puzzling for children because they blend features of living and non-living kinds. This blend makes their placement into one category or another problematic. One question is how children manage the challenge to their categorization scheme. Previous research has revealed some variability in children's ability to understand robots—across different studies children of the same age will sometimes imbue robots both with features of living and non-living things, and at other times treat them exclusively as machines (Jipson & Gelman, 2007; Mikropoulos et al., 2003; Okita & Schwartz, 2006; Saylor, Somanader, Levin, & Kawamura, in review). However, this variability may be the result of differences in experimental methodology making the patterns seen across studies difficult to interpret. The present work improves on this previous work by systematically varying the features and behavior of a robot in a single study.

The basic method in previous studies was to ask children about properties of living things (e.g., biological properties such as being hungry) and non-living things (e.g. mechanical properties such as having wires) to observe which of these properties children extended to robots. The researchers then evaluated whether children treated robots like living things by extending high levels of psychological and biological properties, or non-living things by extending high levels of mechanical properties.

Previous research has revealed a somewhat mixed picture of preschoolers' understanding of robots (Jipson & Gelman, 2007; Mikropoulos et al., 2003; Okita & Schwartz, 2006; Saylor et al., under review). These studies suggested that 3-year-olds seem somewhat confused about robots, as their tendency to extend properties to robots is a bit unsystematic (Mikropoulos et al., 2003; Saylor et al., under review). In contrast, while the responding of 4-year-olds is more systematic, their response patterns for properties of living things differ across the studies. In particular, some work suggests that 4-year-olds *do not* systemically attribute features of living things to robots (psychological and biological properties Saylor et al., in review; biological properties in Jipson & Gelman, 2007), while other studies suggest that 4-year-olds *do* attribute features of living things to robots (psychological properties in Jipson & Gelman, 2007; Mikropoulos et al., 2003; Okita & Schwartz, 2006; biological properties, Okita & Schwartz, 2006). These differences make it difficult to understand how children think about robots.

One question is whether children have an essentialist view of complex artifacts such as robots. Psychological essentialism is the theory that people believe there are essences within entities. These essences are shared, non-obvious properties (Gelman, 2004), and should not be affected by changing surface features. The belief that these essences exist is the basis for making judgments about an object's kind (Sloman & Malt, 2003). Consequently, for there to be an essentialist view of robots, people would have to believe that there are inherent, non-obvious properties that all robots share due to their being grouped together. The previous findings may refute this view because children's attributions of at least some of the robots' non-obvious properties (such as origin and cognitive processes like thinking) varied across studies. However, the studies differed in a variety of ways that make using this previous data as evidence either for or against an essentialist view difficult.

One way in which the previous work is not consistent is the variability in how the robots were presented: Saylor et al. (in review) presented children with pictures of robots, while other studies presented children with videos of moving robots (Mikropoulos et al., 2003; Jipson & Gelman, 2007) or live robots (Okita & Schwartz, 2006). One possibility is that children's understanding of robots in pictures versus videos versus live presentations may have affected their responding. This could be an effect of children being exposed to robots in movies and film, and thinking about a live robot in the terms of the fictional robot they've seen on screen. Thus, differences in the responding of 4-year-olds could be due to variations in their understanding of the medium of presentation, rather than the robots themselves. In addition, previous studies used robots that varied in their physical appearance. In some studies, the robots looked like a person (Mikropoulos et al., 2003; Saylor et al., in review), while in others they had the appearance of an animal (Jipson & Gelman, 2007; Melson et al., 2005; Okita & Schwartz, 2006). These similarities to living entities make it harder to interpret children's responses as they may use their knowledge of the entity that the robot resembles to help them respond to questions (Okita & Scwhartz, 2006).

The current study resolves these difficulties by presenting children with live robots that have an appearance that is neither clearly human nor clearly animal. As a result, we can investigate whether surface features affect children's views of robotic entities. If preschoolers have an essentialist view of robots, they will generalize certain properties across the different kinds of robots even though their surface features differ. However, if they base their categorizations on specific surface features (rather than an essence), then children will not generalize properties across the different kinds of robots. In the current study, we vary two surface features: appearance and the origin of motion.

We manipulated appearance because this factor an important one that children use to categorize robotic entities. Inanimate objects that resembled more prototypical non-living objects (e.g., a sensor box or a TV) tend to receive lower attributions of properties of living-things from children (Jipson & Gelman, 2007; Mikropoulos et al., 2003; Saylor et al., in review). Thus, perceptual similarity to living things may be one factor that leads children to attribute living properties to robots.

In addition to appearance, robots often possess other potentially confusing qualities. One other feature of robots' behavior that may make them puzzling for children is that they move around a room in what seems to be an autonomous fashion even though a person operator often controls them from a distance. For example, a remote control makes the entertainment robot known as RoboRaptor "search for food" in a room by moving around on its own. This may present a puzzle about the origin of the robot's immediate actions because a child has to look past the fact that the robot appears to be moving on its own to understand that there is a person's intention behind the robot's behavior.

Children's understanding of the origin of an entity's actions is intimately connected with their categorization of that entity. This is especially true when it comes to making the distinction between living and non-living things (Gelman, 1990; Gelman et al., 1995; Gelman & Kremer, 1991; Massey & Gelman, 1988). For example, Massey and Gelman (1988) found that children differentiated between entities that could and could not move by themselves. The main factor was that children recognized that animals can move by themselves while man-made objects cannot (even if the man-made object looks like a living thing—as a statue does). Additionally, in a study by Gelman & Kremer (1991), children by the age of 4 attributed internal causes to actions of artifacts. For example, children understood that having wires inside helps a telephone ring. This study suggests that children can use category membership to make predictions about the origins of an entity's actions. In the current study, I investigated whether children used origin of motion to help categorize complex entities such as robots by showing children robots with both internal and external origins of motion observing whether their response patterns change based on these differences.

Although the effects of appearance and origins of motion on children's understanding of living and non-living things have been examined in separate studies previously, there current research provides an in-depth investigation into how both of these are specifically tied to preschooler's categorization of robots within a single study.

Four- and five-year-old children were exposed to one of three versions of a single robot. One group of preschoolers saw a robot with visual similarities to a living thing and internal origins of behavior, while another saw a robot with visual similarities to a living thing but an external origin of behavior. A third group saw a robot with less visual similarity to a living thing but that still possessed an internal origin of behavior. To investigate the effects of appearance and origins of motion, we asked 4- and 5-year-olds to indicate whether the robots had several psychological, biological, and mechanical properties. These observations provide insight into whether children have essentialist views about robots, or instead base their attributions on the individual robot's surface characteristics. If preschoolers have an essentialist view of robots, then we would expect their pattern of responses to remain the same regardless of the robot with which they were presented. If preschoolers base their attributions on the surface features of the robots, then their response patterns should differ between the three conditions.

CHAPTER II

METHOD

Participants

Ninety-eight children participated in the study: Fifty 4-year-olds (Mean age = 56 months, 25 females, 25 males) and 48 5-year-olds (Mean age = 67 months, 25 females, 23 males). Participants were recruited from a metropolitan area in the Southern United States and were primarily from upper-middle class households. An additional 14 children participated but had to be omitted for equipment error (6), experimenter error (3), failure to pass pre-test questions (3), non-compliance (1), and sibling interference (1).

Design

A between-subjects design was used. Children were assigned to one of three experimental conditions in which the appearance and origin of movement of a robot differed. In the *Living-Autonomous* condition (17 4-year-olds (11 males, 6 females) and 16 5-year-olds (8 males, 8 females)), the robot moved in an autonomous way (there was no visible controller when the robot moved). Additionally, the robot was assembled to have surface features of a living thing (e.g., head, eyes, a proper name) (See Figure 1). In the *Living-Controlled* condition (17 4-year-olds (7 males, 10 females) and 16 5-year-olds (6 males, 10 females)), the robot was the same as that in the *Living-Autonomous* condition, but it moved when an experimenter pressed buttons on a large remote control (described below). In the *Nonliving-Autonomous* condition (16 4-year-olds (7 males, 9 females) and 16 5-year-olds (9 males, 7 females), the robot appeared to move independently as it did in the *Living-Autonomous* condition, but the head and eyes were removed so that it looked more like a machine, and it was now labeled by the basic name "robot" (see Figure 2).

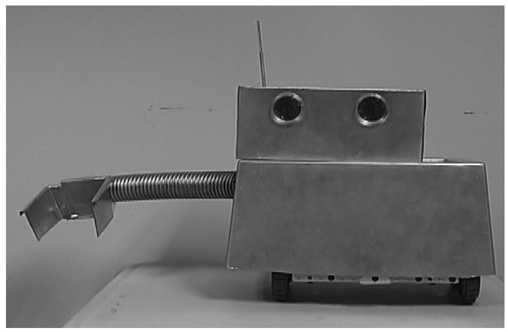


Figure 1. Robot fully assembled for the *Living-Autonomous* and *Living-Controlled* conditions.

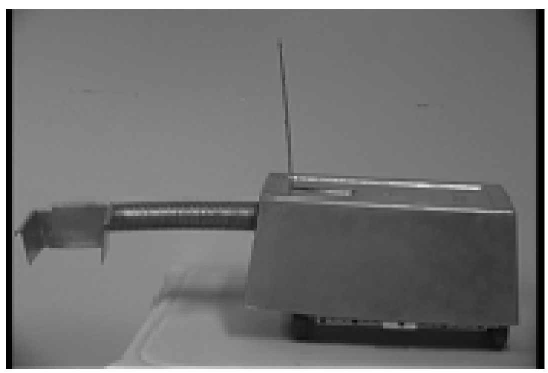


Figure 2. Robot fully assembled for the *Nonliving-Autonomous* condition.

Materials and Equipment

Children were shown 3 pretest items (a couch, a rug, and a camera) and 3 target items (a person, a 13 inch TV/VCR, and the robot). The person and the TV were used as examples of familiar living and non-living things. Children answered questions about them to help determine whether they understood our test questions.

The robot was constructed using a VEX robotics design system that was purchased at RadioShack. This system included components to make a remote controlled robotic entity that could perform multiple actions simultaneously. Additionally, two inflatable rubber balls were used for the robot to hit. One was colored green, the other red. A puppet was also used to ask the children test questions. The puppet was a small hand puppet that looked like a purple frog. Two Mini-DV video cameras were also used to record each session.

Two buttons were constructed to serve as the remote control for the robot in the *Living-Controlled* condition. The buttons for the remote were made from large plastic containers that were painted, one green and the other red.

Children were asked 14 questions about each target item. Four of the questions were about psychological properties (seeing, thinking, counting, and remembering), three were about biological properties (hunger, having a mother, being alive), and seven were about mechanical properties (being put together, being taken apart, breaking, having metal inside, having wires inside, powering on, and being a machine). Questions from the biological and psychological domains referred to properties that living animal-like entities have, while questions about mechanical properties were features that familiar artifacts have. Questions were printed on 4 in X 6 in index cards. For a complete list of the questions, see Table 1.

Table 1

Test Questions. Names were inserted into blanks (E2 name, Sparky/Robot, TV)

Question Type	
Psychological	Can ____ see you? Can ____ think? Would _____ remember me if I left? Can _____ count to five?
Biological	Does _____ get hungry? Does _____ have a mommy? Is _____ alive?
Mechanical	Did someone else put _____ together? Can a grown up take _____ apart? Can _____ break? Does _____ have metal inside? Does _____ have wires inside? Can you turn _____ on? Is _____ a machine?

Procedure

The study was divided into 2 phases: the *robot exposure* and the *test phase*. During the robot exposure phase, children were introduced to the robot and during the test phase children were asked test questions.

There were two experimenters involved in this study. The primary experimenter (E1) interacted with the child, and asked them the questions during the test phase. The secondary experimenter (E2) controlled the robot and also was the person being asked about and recording the responses of the child during the test phase.

Robot exposure

The lab room was split horizontally down the middle using a white line on a carpet. The child and E1 remained on one side of the line, while the robot was on the other side. The child was instructed that he or she could not cross the line at any time. E1 and the child sat at a table facing the robot. E2 remained in a separate room and watched so he could control the robot through a two-way mirror. The child remained unaware of the fact that a second experimenter was involved. The robot was positioned in between the 2 colored balls. The child was told that he or she was going to play a game with the robot.

In the *Living-Autonomous* condition, the child was told the robot's name was "Sparky." He or she was then asked to repeat the name twice to make sure he or she understood that when E1 referred to Sparky she meant the robot. 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 was watching through a two-way mirror, to move the robot. The robot then oriented toward one of the balls, moving in a straight line toward the ball. The robot stopped directly in front of the ball, hit it only one time, and then moved backwards to its original position. E1 then would say, “Let’s watch Sparky do it again!”, and the robot repeated the procedure for the other ball. As the robot approached each ball, E1 narrated the actions by saying, “Sparky is going to hit the ball!”, and as the robot hit the ball they said “Sparky hit the ball!”

The *Nonliving-Autonomous* condition was the same, except that the robot was not named. Instead, it was referred to by its basic category name “robot” in all instances instead of by the name “Sparky”. We also referred to the robot with the pronoun “it” instead of “he” or “him”. These changes were done to help convey the non-living nature of the robot along with removing the robot’s head.

The *Living-Controlled* condition was also the same as the *Living-Autonomous* condition, except for changes highlighting that an experimenter controlled the robot. Specifically, this condition created the illusion to the child that E1 was controlling the robot, even though it still was actually being controlled by a hidden E2. First, two large, obvious buttons were placed in view on the table. Next, after telling children the name of the robot, E1 said “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 then this information pointing at the button and the ball each time she mentioned them. She then said “Sparky’s going to hit the ball!” before pressing one of the buttons. Immediately after the button was pressed, E2 made the robot move, so the robot’s motion appeared to be contingent on E1 pressing the buttons.

Test Phase

After the robot hit both balls and returned to its primary position, E1 said, “Now we are going to play a different game!” The child was then introduced to our puppet, whose name was “Franklin”, who was used to ask the test questions to keep the child engaged in the task. The child was then informed she would be asked yes or no questions, but it was ok to say “I don’t know.” She was then was asked 6 preliminary questions: 3 that required her to identify objects in the room (e.g. “Is that a couch?” and 3 that confirmed that she could answer both yes and no (e.g. “Is that couch blue?”). All but 3 children answered all of the preliminary questions correctly, and those children only missed one question each. After the preliminary questions, the child was told that he or she would be asked about other things in the room, but that they “needed someone else to play”. E1 then said that her friend was doing work in the next room, knocked on the door, and asked E2 to come watch the child play a game with Franklin. E2 then said “I’ll bring my work out here!” and proceeded to bring a clipboard with the response sheet on it out and to sit in a chair placed next to the robot. E2 then scored the child’s responses to the test questions.

The child was then asked 14 yes/no questions about the robot, a familiar non-living thing (e.g. a TV), and a familiar living thing (e.g. a person, the second experimenter) for a total of 42 questions. The questions investigated children’s attributions of psychological, biological, and mechanical features for the entities (see Table 1 for more detail). Question order was determined randomly, with E1 shuffling all of the cards before asking the questions.

The child was then given a final, forced choice question designed to investigate what they thought made the robot move. They were asked whether they thought "the robot moved by itself" or "if something else made it move". If the child responded that something else made it move, they were asked, "What made it move?" In both the *Living-Autonomous* and *Living-Controlled* conditions, the pronouns "he" or "him" were used in referring to the robot in addition to the name "Sparky". In the *Nonliving-Autonomous* condition the pronoun "it" was used in addition to calling the robot by its basic category.

For all three conditions, the order in which the robot hit the balls was randomized, as well as the order in which the options in the final question about what made the robot move were offered.

Coding

A yes response was coded as a 1 and a no response was coded as a 0. Levels of attribution of psychological, biological and mechanical properties were then calculated as a percentage of yes responses out of total responses for each property type. When a child said "I don't know" or failed to respond to a test question we omitted the response to that test question from analysis. This happened rarely: out of 4110 responses, 182 were *Don't Know/No response* (4.43%).

CHAPTER III

RESULTS

Because we were interested in children's categorization of a novel entity (the robot) we needed to be certain that they understood the test questions so we could interpret their response pattern. For this reason, as a first step, we asked whether 4- and 5-year-olds understood our test questions by comparing their responding to questions about the familiar TV and person to chance levels using binomial tests. We reasoned that if children could not respond reliably to these well understood entities, then there was a possibility that they did not understand the questions being asked. We conducted the comparisons separately by age and for each familiar entity. Results indicated that both 4- and 5-year-olds responded in the expected manner for all questions asked about the person (binomial p's $< .002$). However, the results indicated more variability in children's responding to the TV. Results of the binomial test suggested that 4-year-olds were at chance for four questions about mechanical properties: "Can the TV break?" (28 out of 49 said yes, $p = .39$), "Can a grownup take the TV apart?" (17 out of 47 said yes, $p = .08$), "Does the TV have metal inside?" (20 out of 45 said yes, $p = .55$), and "Is the TV a machine?" (19 out of 46 said yes, $p = .30$). For all of the other questions about the TV, 4-year-olds responded reliably in the expected directions (binomial p's $\leq .05$). Five-year-olds' responding to the questions about the TV indicated that they understood each of the test questions as well (binomial p's $< .03$) except for two questions about mechanical properties: "Does the TV have metal inside?" (24 out of 42 said yes, $p = .44$) and "Can a grown-up take the TV apart?" (26 out of 43 said yes, $p = .22$). Because children had difficulty answering these questions, in the analyses that follow, we chose to omit the 4 questions about mechanical properties where children's level of responding did not differ from chance.

Psychological property analyses

To investigate children's tendency to attribute psychological properties to the entities we conducted a 2 (Age: 4-year-olds versus 5-year-olds) X 3 (Condition: *Living-Autonomous*, *Living-Controlled*, *Nonliving-Autonomous*) MANOVA on responding to the Person, TV, and robot. The analysis revealed a main effect of Age (F (3, 89) = 3.31, $p = .02$, $\eta_p^2 = .10$) and Condition (F (6, 180) = 3.53, $p = .002$, $\eta_p^2 = .11$).

Univariate ANOVAs revealed that responding to the person did not differ across age (F (1,91) = 1.43, $p = .23$, $\eta_p^2 = .02$) (See Figure 3). The main effect of Age was due to 4-year-olds attributing more psychological properties than 5-year-olds to the TV (F (1, 91) = 4.05, $p = .05$, $\eta_p^2 = .04$) and to the robot (F (1,91) = 6.99, $p = .01$, $\eta_p^2 = .07$) (See Figures 4 and 5).

Univariate ANOVAs revealed that the main effect of condition was the result of differences in children's responding to the robot (F (2,91) = 8.87, $p < .001$, $\eta_p^2 = .16$). Planned comparisons revealed that for the robot, attributions of psychological properties were significantly higher in the *Living-Autonomous* condition than both the *Living-Controlled* condition ($p = .03$) and the *Nonliving-Autonomous* condition ($p < .001$). Additionally, it was found that psychological attributions in the *Living-Controlled* condition were significantly higher than in the *Nonliving-Autonomous* condition (p =

.05). Thus, the condition in which the robot had the most living surface features (both appearance and origin of motion) had the most psychological attributions, and when a living appearance or living origin of motion was removed, psychological attributions became significantly lower. Additionally, psychological attributions were significantly lower in the condition in which living appearance was removed as compared to the condition in which a living origin of motion was removed. This pattern of results suggests that preschoolers use both their knowledge of appearance and origin of motion to categorize novel entities, but that appearance is control to their categorization (See Figure 5).

To evaluate how reliable children's responding was for the robot for psychological attributions, we conducted one-sample t tests against a chance value of .50 separately for each Age and Condition. For the *Living-Autonomous* condition, 4-year-olds' responding was *above* chance (t (16) = 3.58, p = .002). For the *Living-Controlled* (t (16) = .20, p = .84) and *Nonliving-Autonomous* (t (15) = 1.40, p = .18) condition, 4-year-olds were at chance.

Five-year-olds were at chance in both the *Living-Autonomous* (t (14) = .44, p = .67) and *Living-Controlled* (t (15) = 1.53, p = .15) conditions. For the *Nonliving-Autonomous* condition, 5-year-olds were *below* chance (t (15) = 4.87, p < .001).

Biological property analyses

A 2 (Age: 4-year-olds versus 5-year-olds) X 3 (Condition: *Living-Autonomous*, *Living-Controlled*, *Nonliving-Autonomous*) MANOVA on responding to the Person, TV, and robot was performed for biological properties. The analysis revealed a main effect of

Age (*F* (3,88) = 4.62, $p = .005$, $\eta_p^2 = .14$). There was no main effect of Condition (*F* (6,178) = 1.06, $p = .39$, $\eta_p^2 = .04$) and no significant interaction between Age and Condition (*F* (6,178) = 1.09, $p = .37$, $\eta_p^2 = .04$).

Univariate ANOVAs were performed to investigate the main effect of Age. There were no differences in Age for responding to the person (*F* (1,90) = 2.15, $p = .15$, $\eta_p^2 = .02$) (See Figure 3). It was found that the main effect was the result of 4-year-olds giving more biological attributions for the TV (*F* (1,90) = 8.11, $p = .005$, $\eta_p^2 = .08$) and the robot (*F* (1,90) = 7.20, $p = .009$, $\eta_p^2 = .07$) than 5-year-olds (See Figures 4 and 5).

To evaluate the reliability of children's responding to the biological questions about the robot, we conducted one-sample t tests against a chance value of .50 separately for each Age and Condition. For the *Living-Autonomous* condition, 4-year-olds were at chance (*t* (16) = .70, $p = .50$). Four-year-olds in the *Living-Controlled* (*t* (16) = 2.27, $p = .04$) and the *Nonliving-Autonomous* (*t* (15) = 4.21, $p = .001$) were both *below* chance.

Five-year-olds were below chance in the *Living-Autonomous* (*t* (13) = 4.08, $p = .001$), *Living-Controlled (*t (15) = 4.21, $p = .001$), and the *Nonliving-Autonomous* (*t* (15) = 5.22, $p < .001$) conditions for biological attributions to the robot.

Mechanical property analyses

A 2 (Age: 4-year-olds versus 5-year-olds) X 3 (Condition: *Living-Autonomous*, *Living-Controlled*, *Nonliving-Autonomous*) MANOVA on responding to the person, TV, and robot was performed for mechanical properties. The analysis revealed a main effect of Age (*F* (3,89) = 9.08, $p <.001$, $\eta_p^2 = .23$) and an interaction between Age and

Condition (F (6,180) = 2.17, p = .05, η_p^2 = .07). There was no main effect of Condition (F (6,182) = .95, p = .46, η_p^2 = .03).

The main effect of Age was the result of differences in responding between age for all three entities. For the person (F (1,92) = 6.43, p = .01, η_p^2 = .07), the difference was that 4-year-olds were more willing to attribute mechanical properties to the person than 5-year-olds (See Figure 3). For the TV (F (1,92) = 8.714, p = .004, η_p^2 = .09) and the robot (F (1,92) = 12.08, p = .001, η_p^2 = .12), the difference was in the fact that 5-year-olds were more willing to attribute mechanical properties to those entities than 4-year-olds (See Figures 4 and 5).

Additionally, Univariate ANOVAs for the Age X Condition interaction revealed that the interaction was significant for both the TV (F (2,91) = 3.84, p = .03, η_p^2 = .08) and the robot (F (2,91) = 3.17, p = .05, η_p^2 = .07). Planned comparisons were performed to investigate these results further. These comparisons revealed that for both the TV (p = .01) and the robot ($p < .001$), 5-year-olds attributed significantly higher levels of mechanical properties in the *Living-Controlled* condition than 4-year-olds. This did not occur in any of the other conditions. This finding suggests that when 5-year-olds observed a remote control, it may have made them think more about the mechanical properties of the non-living entities in general. This may have resulted in increased attributions of these mechanical properties for both the TV and robot.

To evaluate how reliable children's responses to the mechanical questions for the robot were, we conducted one-sample t tests against a chance value of .50 separately for each Age and Condition. Four-year-olds who saw the robot with both a living appearance and origin of motion (*Living-Autonomous*: t (16) = 1.88, p = .08) and those who saw the robot with only a living origin of motion (*Nonliving-Autonomous*: t (15) = 3.0, p = .01) were *above* chance in their mechanical attributions to the robot. Those that saw the robot with only a living appearance (*Living-Controlled*: t (16) = .52, p = .61) were at chance in their attributions.

Five-year-olds attributed these properties at levels significantly *above* chance for the *Living-Autonomous* (t (15) = 4.99, $p < .001$), *Living-Controlled* (t (15) = 12.31, $p < .001$), and *Nonliving-Autonomous* (t (15) = 4.06, p = .001) conditions.

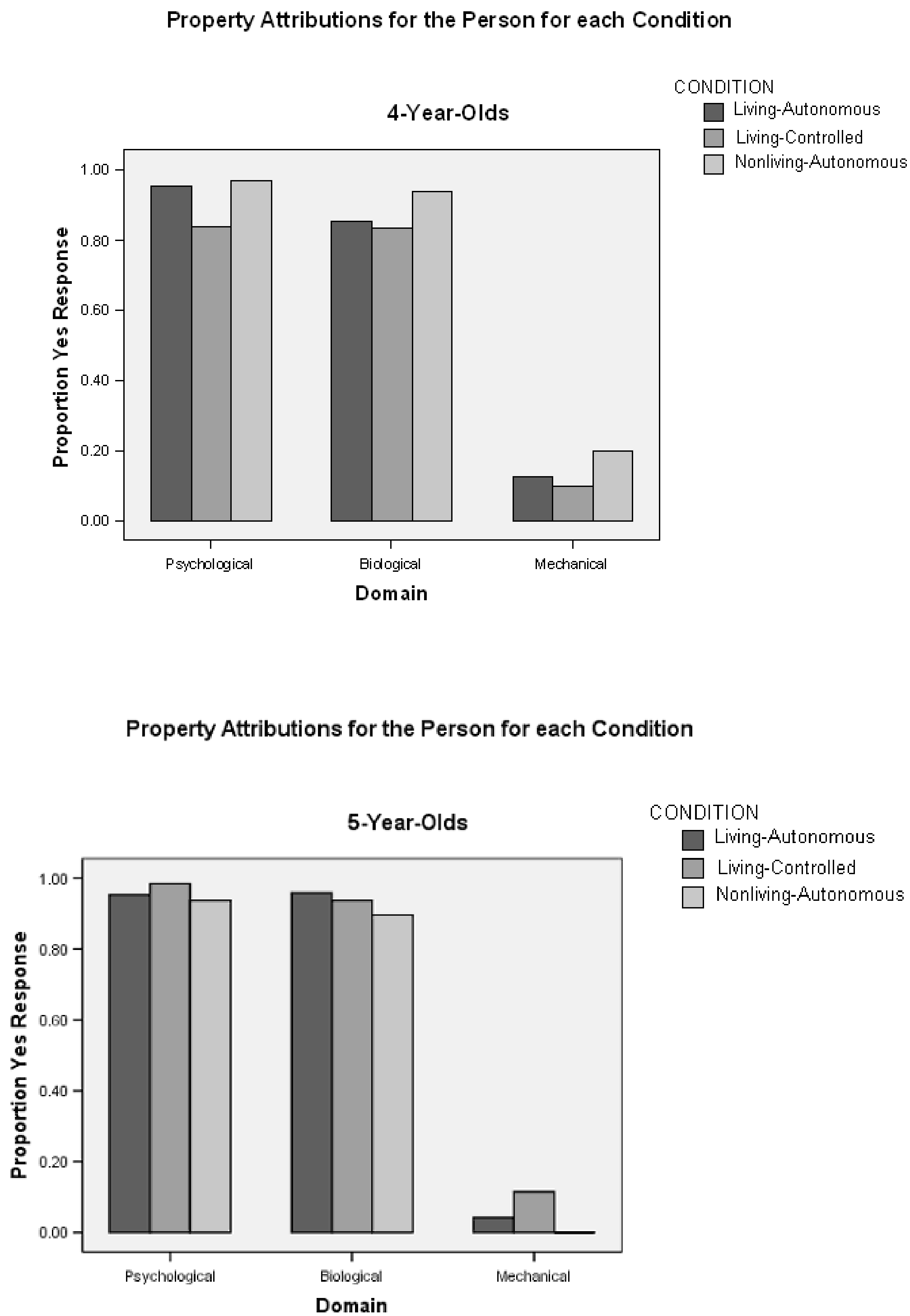
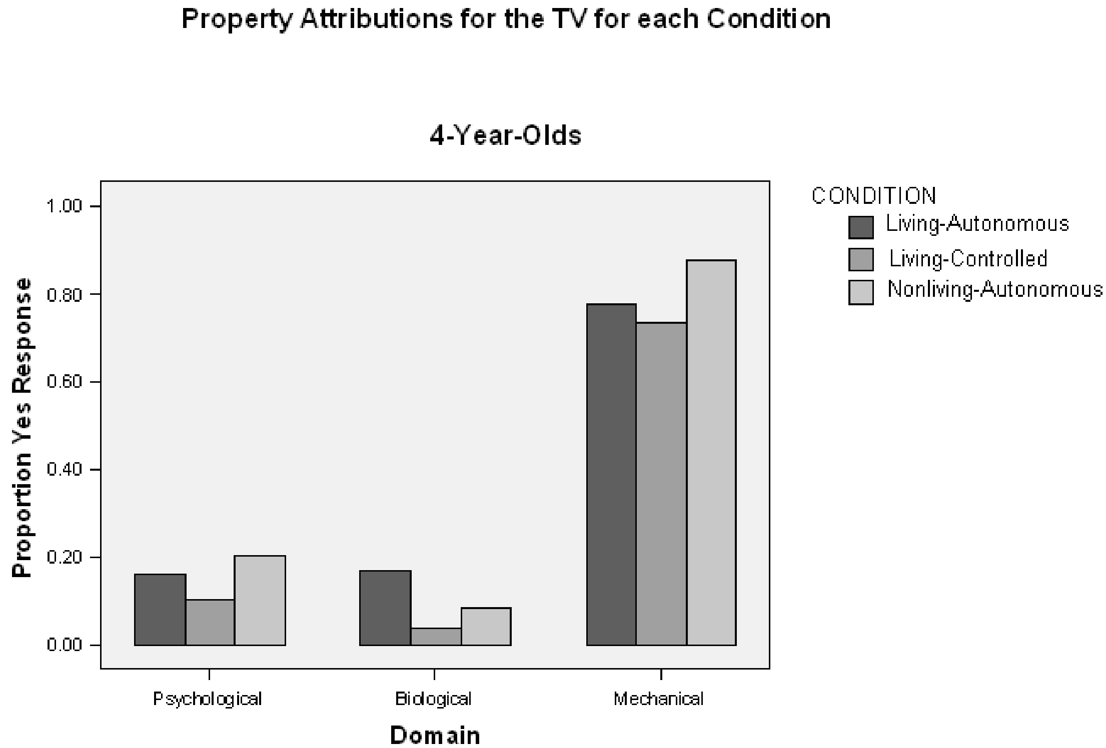


Figure 3. Proportion yes response for the person for condition across age.



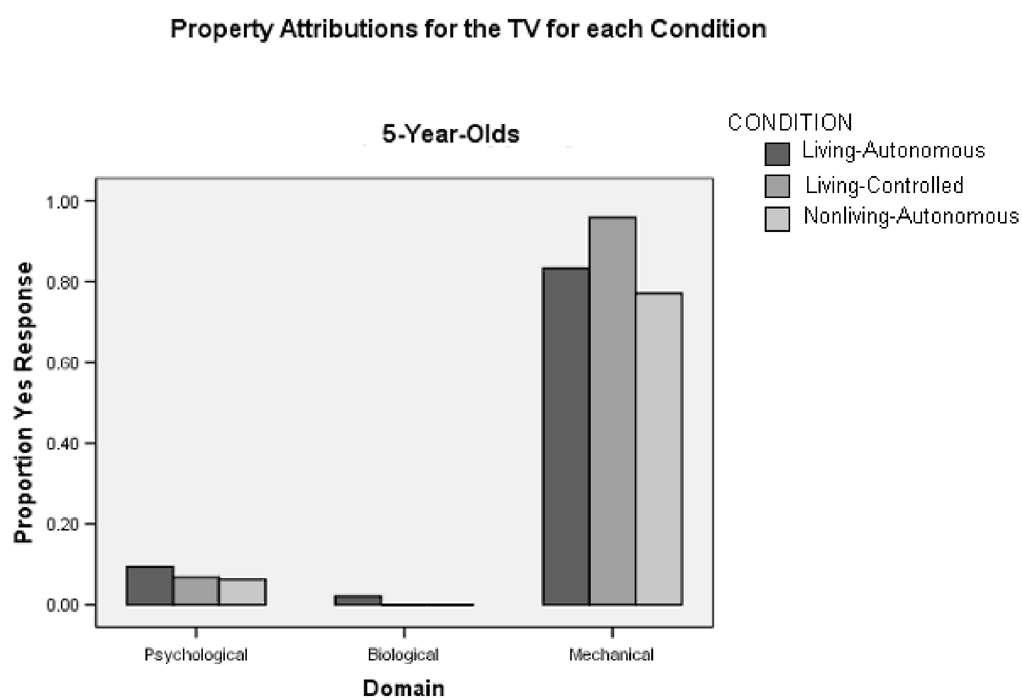


Figure 4: Proportion yes responding for the TV for each condition across age.

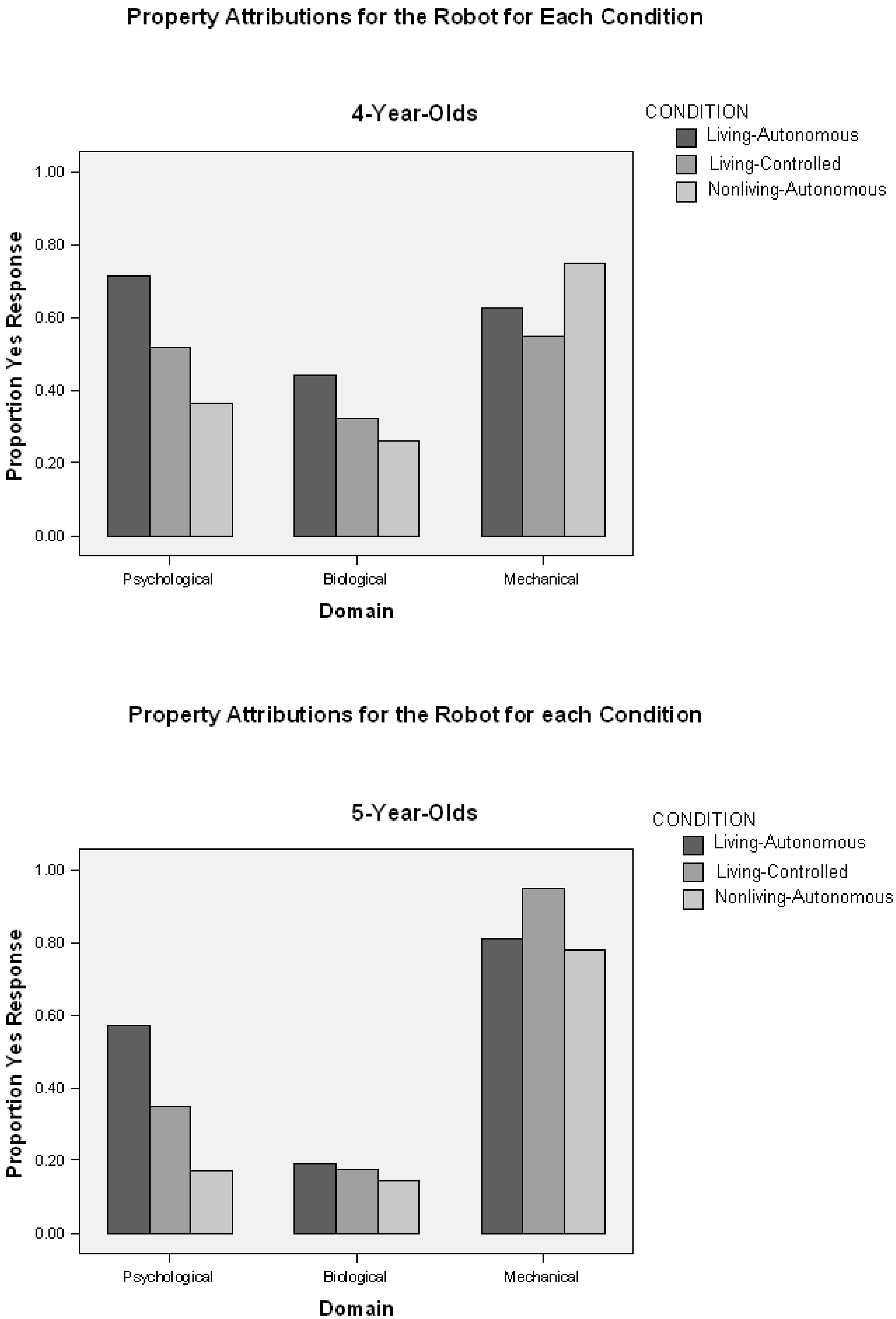


Figure 5: Proportion yes responding for the robot for each condition across age.

Analysis of children's beliefs about robot movement

The final analysis was performed to examine children's beliefs about how the robot moved. At the end of the procedure children were asked the question, "Did the robot move by itself, or did something else make it move?" We examined how many children believed the robot moved by itself using binomial tests for each Age and Condition. For the *Living-Autonomous* and *Nonliving-Autonomous* conditions, children were expected to be at or above chance in their assertions that the robot moved on its own. However, it was expected that in the *Living-Controlled* condition, children would be significantly below chance in their assertions of the robot moving by itself because they had seen the remote control explicitly directed the robot's movements.

The analysis revealed that for 4-year-olds in the *Living-Autonomous* condition there was a trend in saying that the robot moved by itself (11 out of 15 said yes, $p = .12$) while in the *Nonliving-Autonomous* condition they were significantly above chance in saying that the robot moved by itself (12 out of 14 said yes, $p = .01$). Thus, 4-year-olds followed our expectations in these two conditions. However, in the *Living-Controlled* condition, 4-year-olds were at chance in asserting that the robot moved by itself (9 out of 17 said yes, $p = .99$) instead of below chance. This finding suggests that even though 4-year-olds appeared to understand the effects of the remote control revealed by the differences discussed above, they may not fully understand that the remote controlled all of the robot's actions.

Five-year-olds in the *Living-Autonomous* condition also showed a trend to say the robot moved by itself (11 out of 15 said yes, $p = .12$), while in the *Nonliving-Autonomous* condition, they did not differ from chance in their responding (11 out of 16 said yes, $p =$

.21). Additionally, in the *Living-Controlled* condition, 5-year-olds were significantly *below* chance (0 out of 16 said it moved by itself, $p < .001$) in their assertions that the robot moved by itself. Thus, 5-year-olds responded in the pattern we expected, suggesting they understood the causes of the robot's behavior.

Summary of Results

The analyses of responses for the robot revealed a developmental difference in responding between 4- and 5-year-olds in each question domain. For psychological and biological domains, 4-year-olds attributed significantly more of the properties to the robot than 5-year-olds. However, for mechanical properties, 5-year-olds attributed significantly more properties to the robot than 4-year-olds. This result suggests that 5-year-olds have a clearer understanding of the non-living nature of the robot than 4-year-olds.

Only psychological properties varied robustly across conditions. Children in the condition with the greatest surface similarity to a living thing (both a living appearance and an internal origin of motion) attributed significantly higher levels of psychological properties than children in the conditions where the robot lost its living appearance or the internal cause of motion. This suggests that preschoolers were sensitive to both a change in the appearance and origin of motion of a robot when making categorizations on the basis of psychological properties. Children in the condition with the remote controlled robot with a living appearance attributed more psychological properties to the robot than those in the condition in which the robot did not have a living appearance, but still moved on its own. These results suggest that children may be more sensitive to appearance than origin of motion, even though they do use both in their property attributions.

For the biological and mechanical properties, differences in appearance and origin of motion did not change the overall level of responding. However, there was some hint that mechanical and biological attributions were affected by differences in the robot's appearance and origin of motion. For biological properties, when the robot most resembled a living thing, four-year-olds were above chance in their attribution of biological properties while 5-year-olds were at chance. When the robot lost the appearance of a living thing or was given an external cause of motion, 4-year-olds level of biological attributions dropped to chance levels and 5-year-olds level of attribution were below chance.

For mechanical properties, a change across conditions only occurred with 4-year-olds. In the conditions in which the robot maintained a living appearance, 4-year-olds were at chance for their levels of mechanical attributions. However, in the condition in which the robot lost its living appearance, they attributed mechanical properties at levels above chance. This result suggests that appearance may affect 4-year-olds understanding of the mechanical properties of robots

CHAPTER IV

GENERAL DISCUSSION

This study investigated whether changes in a robot's appearance or origins of motion affected preschoolers' categorization. The results showed that children's attributions of psychological properties, such as the ability to see or think, were affected by changes in these two dimensions. In contrast, these features did not affect children's attributions of biological or mechanical properties across conditions in the same way. This finding suggests that children have a more flexible understanding of psychological properties than biological or mechanical ones when it comes to robots. This finding also helps resolve the differences found in previous work (Jipson & Gelman, 2007; Melson et al., 2005; Mikropoulos et al., 2003; Okita & Schwartz, 2006; Saylor et al., in review) in which the patterns of property attributions to various robots differed. It suggests that preschoolers think that some robots have psychological properties, but their beliefs about this may be changed based on the surface features of that robot. Specifically, this belief in a robot's possession of psychological properties is susceptible to the factors of both appearance and the origin of motion that governs the robot.

This study examined whether children have essentialist beliefs about robotic entities. The results do not support an essentialist view of robotic entities. Children's responses about psychological properties changed based on surface features. This would suggest that their understanding of the non-obvious properties of a robot has changed based on the surface features of the robot seen. Additionally, though no relative change across conditions was found for biological or mechanical properties, there were differences in the reliability of children's responding across condition. Both 4- and 5-year-olds dropped their biological attributions when either a living appearance or an internal origin of motion was removed from the robot. Additionally, 4-year-olds attributed mechanical properties on levels above chance once a living appearance was removed from the robot. Thus, the current study suggests that children do not have an essentialist view of complex artifacts such as robots. Future studies should further investigate this matter with a more comprehensive look into how children's different property attributions change across robots with different surface features.

Another implication of this work is that preschoolers may treat robots, and other complex non-living things, as mixed entities in some circumstances. For example, 4-year-old children attributed psychological and mechanical properties at levels above chance to an anthropomorphized robot that moved like a living thing. These findings suggest that preschoolers are sometimes willing to attribute both living and non-living properties to a novel entity such as a robot. Additionally, because their levels of biological attributions were below chance in some conditions, it suggests that high levels of psychological attributions do not necessarily indicate that children think of an entity as a biological being.

This work suggests that children can use surface behaviors like appearance and motion to revise their hypothesis about what abilities a robot has, including the idea of it having a mind. However, when the living appearance of the robot was removed, children's psychological attributions fell to lower levels than when only the living origin of motion was removed. One explanation for this is that children failed to understand the remote control. This seems unlikely because even though 4-year-olds in the condition with the remote control did not say something made the robot moved, 5-year-olds in that condition did. Thus, 5-year-olds did have a clear understanding of the fact that when a remote was present, the cause of the robot's movement was an external one. Another possibility is that observable physical features may be more central to the classification of artifacts than non-visible internal features.

Previous research offers some support for this possibility. In particular, appearance has been shown to be a strong factor in children's understanding of robots in other studies. Jipson & Gelman (2007) found that children were more likely to attribute living properties to a robot dog than a more inanimate looking sensor box. Additionally, in a study with older children, Woods, Dautenhahn, & Schulz (2005) found that children thought of more anthropomorphic robots as having a capability for more psychological properties (e.g. emotion). However, neither study included a contrasting case where internal mechanisms of living things were given to the robot, while its outer appearance was more machine like. The present study therefore fills a gap left by the previous literature by providing suggestive evidence that observable outer features may be given priority over behavioral or internal ones when children categorize complex artifacts like robots.

One possible application of this work is that if preschool children think of robots as psychological beings, they may even think of them as viable learning or social partners. Thus, it may be possible for educators and toy manufacturers to make more productive use out of robotic entities. However, it would be important to investigate how children would learn from robotic entities, and whether the knowledge gained from robots would be as rich and deep as that gained from human influences. This is a fascinating question for future work.

This research not only furthers our understanding about how children perceive the increasingly common phenomenon of robotic entities, but how they deal with novel entities in general. For one, it first suggests that there is a developmental difference in how 4- and 5-year-old children understand these novel robotic entities. Additionally, the current research suggests that preschoolers have a relatively stable understanding of the biological and mechanical properties of robots across different surface features, while their understanding of the psychological nature of a robot is much more susceptible to the influence of factors like appearance and the causal mechanisms behind its behavior. The current work suggests that preschoolers are willing to think of robots as mixed entities, which means they can possess properties of both living and non-living things. This suggests flexibility in their categorization of the robots that may not exist as children grow older and their categories become more mature. Though further research is necessary to fully understand children's categorization, the current study helps to understand the flexibility in preschooler's categorization of novel objects.

APPENDIX A: TABLES

Table 2

Mean percentage of yes responses for individual questions for the Person across age and condition. The name of E2 was inserted into the blank.

Question			
	Living-Autonomous	*Living-Controlled*	*Nonliving-Autonomous*
Can ____ see you?			
4-Year-Olds:	88	94	100
5-Year-Olds:	94	100	94
Can ____ think?			
4-Year-Olds:	100	88	94
5-Year-Olds:	100	94	87
If I left, would ____ remember me?			
4-Year-Olds:	94	69	94
5-Year-Olds:	93	100	94
Can ____ count to five?			
4-Year-Olds:	100	94	100
5-Year-Olds:	94	100	100
Does ____ get hungry?			
4-Year-Olds:	100	88	100
5-Year-Olds:	94	93	94
Does ____ have a mommy?			
4-Year-Olds:	71	71	88
5-Year-Olds:	94	87	73
Is ____ alive?			
4-Year-Olds:	88	88	94
5-Year-Olds:	100	100	100
Can ____ break?			
4-Year-Olds:	6	13	31
5-Year-Olds:	19	7	0
Did someone else put ____ together?			
4-Year-Olds:	31	21	20

5-Year-Olds:	13	31	0
Could a grown-up take ___ apart? 4-Year-Olds: 5-Year-Olds:	 13 7	 18 13	 13 0
Does ____ have metal inside of it/him? 4-Year-Olds: 5-Year-Olds:	 24 6	 6 0	 20 6
Can a grown-up turn ____ on? 4-Year-Olds: 5-Year-Olds:	 0 0	 6 0	 27 0
Does ____ have wires inside? 4-Year-Olds: 5-Year-Olds:	 13 0	 6 0	 13 0
Is ____ a machine? 4-Year-Olds: 5-Year-Olds:	 0 0	 6 0	 0 0

Table 3

Mean percentage of yes responses for individual questions for the TV across age and condition.

Question			
	Living-Autonomous	*Living-Controlled*	*Nonliving-Autonomous*
Can the TV see you?			
4-Year-Olds:	18	18	25
5-Year-Olds:	6	6	0
Can the TV think?			
4-Year-Olds:	0	6	13
5-Year-Olds:	7	6	0
If I left, would the TV remember me?			
4-Year-Olds:	35	13	40
5-Year-Olds:	25	13	27
Can the TV count to five?			
4-Year-Olds:	13	6	6
5-Year-Olds:	0	0	0
Does the TV get hungry?			
4-Year-Olds:	0	0	6
5-Year-Olds:	0	0	0
Does the TV have a mommy?			
4-Year-Olds:	13	6	6
5-Year-Olds:	0	0	0
Is the TV alive?			
4-Year-Olds:	35	6	13
5-Year-Olds:	6	0	0
Can the TV break?			
4-Year-Olds:	56	53	63
5-Year-Olds:	67	88	56
Did someone else put the TV together?			
4-Year-Olds:	60	56	80
5-Year-Olds:	64	91	57

Could a grown-up take the TV apart? 4-Year-Olds: 5-Year-Olds:	 31 64	 38 77	 40 44
Does the TV have metal inside of it? 4-Year-Olds: 5-Year-Olds:	 29 43	 46 77	 60 53
Can a grown-up turn the TV on? 4-Year-Olds: 5-Year-Olds:	 100 94	 100 100	 100 100
Does the TV have wires inside? 4-Year-Olds: 5-Year-Olds:	 71 87	 63 93	 80 69
Is the TV a machine? 4-Year-Olds: 5-Year-Olds:	 19 77	 44 93	 64 56

Table 4

Mean percentage of yes responses for individual questions for the robot across age and condition. “Sparky” or “the robot” was inserted into the blank.

Question			
	Living-Autonomous	*Living-Controlled*	*Nonliving-Autonomous*
Can ____ see you?			
4-Year-Olds:	88	65	31
5-Year-Olds:	71	29	6
Can ____ think?			
4-Year-Olds:	56	50	29
5-Year-Olds:	50	31	13
If I left, would ____ remember me?			
4-Year-Olds:	94	56	69
5-Year-Olds:	71	57	38
Can ____ count to five?			
4-Year-Olds:	40	31	33
5-Year-Olds:	33	23	13
Does ____ get hungry?			
4-Year-Olds:	41	31	27
5-Year-Olds:	14	13	6
Does ____ have a mommy?			
4-Year-Olds:	19	12	13
5-Year-Olds:	8	0	6
Is ____ alive?			
4-Year-Olds:	75	53	38
5-Year-Olds:	36	33	31
Can ____ break?			
4-Year-Olds:	56	65	67
5-Year-Olds:	67	87	69
Did someone else put ____ together?			
4-Year-Olds:	67	62	71
5-Year-Olds:	93	100	86

Could a grown-up take ___ apart?			
4-Year-Olds:	25	53	56
5-Year-Olds:	42	77	69
Does ____ have metal inside of it/him?			
4-Year-Olds:	75	67	81
5-Year-Olds:	87	93	93
Can a grown-up turn ____ on?			
4-Year-Olds:	59	53	69
5-Year-Olds:	73	100	69
Does ____ have wires inside?			
4-Year-Olds:	65	50	88
5-Year-Olds:	81	83	80
Is ____ a machine?			
4-Year-Olds:	47	73	100
5-Year-Olds:	80	93	88

Table 5

Percentages for children's responses to the "What made the robot move?" question across age and condition.

Response			
	Living-Autonomous	*Living-Controlled*	*Nonliving-Autonomous*
The robot moved by itself			
4-Year-Olds:	65	47	75
5-Year-Olds:	69	0	31
Something else made the robot move			
4-Year-Olds:	24	41	12
5-Year-Olds:	25	100	56
I don't know/nonsensical			
4-Year-Olds:	12	12	12
5-Year-Olds:	6	0	12

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