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Understanding how children understand robots: Perceived animism in child–robot interaction

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Abstract

Centuries ago, the existence of life was explained by the presence of a soul (Tylor, 1871). Known as animism, this term was re-defined in the 1970s by Piaget as young children's beliefs that inanimate objects are capable of actions and have life-like qualities. With the development of robots in the 21st century, researchers have begun examining whether animism is apparent in children's impressions of robots. The purpose of this study was to use a model of knowledge structures, or schemata, to examine whether children attribute human qualities of cognition, affect, and behavior to a robot. An experiment was set up at a science center located in a major Western Canadian city, and visitors to the center were invited to participate. A total of 198 children ages 5–16 years ($M=8.18$ years) with an approximate even number of boys and girls were included. Children completed a semi-structured interview after observing a robot, a small 5 degree of freedom robot arm, perform a block stacking task. Answers to the nine questions about the robot were scored according to whether they referenced humanistic qualities. Results from frequency and content analyses suggest that a significant proportion of children ascribe cognitive, behavioral, and especially affective, characteristics to robots.

Keywords: Robotics; Children; Developmental psychology; Animism; Child development; Human–robot interaction

1. Introduction

When is something alive? Tylor (1871) suggested that the soul creates life. According to British anthropologist Marett (1914) inanimate objects with a human characteristic or behavior may mysteriously make them seem alive. This tendency to ascribe human characteristics to an inanimate object is defined as animism. Piaget (1929) observed this phenomenon in children through their perceptions of objects such as movement of a cloud or bicycle. Researchers in the 21st century are now examining whether children hold an animistic view towards robots. The purpose of this study was to study animism according to the concept of schemata, which are "knowledge structures" that represent a person's core beliefs about themselves and others (Muran, 1991). These schemata can be classified as representing thoughts, affect, and behaviors. Children's beliefs about a robot according to these three schemata types are examined in this study.

1.1. Animism

For over 50 years, Piaget studied the course of cognitive development from birth to adolescence (Piaget, 1930, 1951; Thomas, 2005). Briefly, he incorporated information gained through observations of and interviews with children into several stages of cognitive development. From the period of age 2–11 years, accordingly, children progress through two stages named preoperational and concrete-operational. Throughout these stages children come to understand and coordinate symbols and mental

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images. During this structuring of thinking abilities children exhibit an 'error' in thinking, which Piaget (1929) named "animism". Specifically, he defined it as "the tendency to regard objects as living and endowed with will" (p. 170). Accordingly, children in this age range tend to assign life to moving inanimate objects. As they develop concepts about the attributes of life they experience, they learn to ascribe life to living objects (i.e., plants and animals) only at the formal operational stage (age 12 years and older).

Although an influential theory in developmental psychology, research shows that Piaget's stage specific age ranges are not consistently supported (Baron et al., 1995; Siegel, 1993). Neither is there systematic evidence of the existence of animism in children between the ages of 2–11 years, and its non-existence at age 12 years and older (Deutsch, 1943; Gelman et al., 1983; Golinkoff et al., 1984; Huang and Lee, 1945; Keil, 1979; Oakes, 1947). Although some children do not exhibit animism and some adults do, there is some evidence that animism tends to decrease with age (Bullock, 1985; Inagaki and Sugiyama, 1988; Simmons and Goss, 1957).

1.2. Animism and robots

Although recent research has moved away from examining stages of animism in children (Sodian and Bullock, 2008), it leaves a legacy as a paradigm for understanding children's beliefs about inanimate objects. Indeed, Holland and Rohrman (1979) concluded that "… Piaget's theory has at least been widely approved for 30 years, and is still ripe ground for investigation", (p. 370). This theory is resurrected here as an important concept in understanding children's perceptions of robots because robots now commonly appear in industrial applications, lab equipment, tourism, health care, and children's toys. Given their increasing integration into society, it is important to ask about children's animistic beliefs about robots.

The definition of animism has been recently extended in its application to how children understand robots. Melson et al. (2009) specified sub-categories of animism including understanding objects as biological according to whether they are alive or dead. Nonbiological objects, in contrast, are those that are or were never alive and may be made by humans (house) or exist in nature (water). Animism, according to Melson et al. (2009), can furthermore be defined as understanding objects according to psychological attributes that include their mental (intentions and desires), social (interactive and friendly), and moral (concern for well being) characteristics. We propose that mental states can be further specified to understand animism. Over many years, theorists have developed and refined the concept of schemata, or beliefs people hold about themselves and others (e.g., Maultsby and Wirga, 1998; Muran, 1991). These schemata consist of cognitive (thoughts), affective (feelings), and motoric (behavioral) information. That is, cognition refers to a person's memory and knowledge; affect refers to emotional responses; and behavior refers to physical abilities and actions. Extended to studying human–robot interactions, we ask whether children credit robots with these abilities, in an effort to apply a comprehensive schemata model of cognitive, affective, and behavioral characteristics.

There is compelling research suggesting that children do exhibit animism towards robots. Michotte (1963) found that when an inanimate object shows motion people may perceive it as being alive. Indeed, a dot moving across the screen while changing directions and speed can illicit animistic responses in college students (Tremoulet and Feldman, 2000). There is also some evidence that children draw pictures of robots with human characteristics (e.g., human face) and can create stories that characterize robots as social beings (Bumby and Dautenhahn, 1999). Moreover, their actions towards a robot may represent animistic beliefs. For example, Pitsch and Koch (2010) found that children adjust and maintain their actions towards a robotic dinosaur, contingent to the robot's reactions to the child. Despite these suggestions of animism, few studies have simultaneously examined cognitive, affect, and behavioral characteristics. Syrdal et al. (2009) provide evidence of behavioral schemata whereby children offer examples of activities for robots that are typical of humans (e.g., helping with their homework). The extent to which children adopt such beliefs was examined by Melson et al. (2005). They found that 89% of children thought that a robotic dog could play with them. They further determined that 33% of children thought a robotic dog could feel embarrassed, and 74% thought it could feel happy; and regarding cognitive abilities, 39% of children thought it could recognize them and 22% stated it would know how they were feeling. Although this study examined various types of schemata, the results are specific to a robotic dog (Sony's AIBO). Thus, past interactions with real dogs by the participants could have caused/triggered such reaction towards the robotic dog (at this time this is unknown and remains an assumption). The purpose of our study is to extend Melson et al.'s results to determine the degree to which children also hold animistic beliefs for a robot that is unique and not designed to represent an animal. In summary, this method allows us to confirm whether past experiences (specifically, lack thereof) impact children's perceptions of various cognitive, affect, and behavioral characteristics simultaneously for one robot.

Considerable resources are being devoted to creating humanistic robots that engage in social interactions with people and complete tasks people find undesirable (e.g., mowing the lawn) or difficult (BNET, 2008; Heerink et al., 2008). A relatively new field of research, developmental robotics, is devoted to programming these robots to exhibit thoughts, feelings, and behaviors in a human-like manner. The purpose of the present study is to explore children's perceptions of these cognitive (the object has the capacity to think), affective (the object experiences feelings), and behavioral (the object can perform functions) characteristics of robots. This study contributes to the existing research on animism in that it uses a schemata-based cognitive-affective-behavioral model to present a broad understanding of animism. In addition, to date there are few studies on animism among children in regards to robots, and these have primarily been examined in relation to a robotic dog (which may be biased by children's understanding of animism in relation to a real dog), and requires exploration with other robots. Moreover, we extend previous research by examining whether children younger than age 12 years are more likely to express these animistic perspectives than do children age 12 years and older.

2. Method

2.1. Sample and procedure

A total of 184 children ($n=98$ female, $n=86$ male) between the ages of 5–16 years ($M=8.18$ years) participated. They were visitors at a science center located in the downtown area of a large city in Western Canada. As they walked through the center they were approached by a researcher, if they appeared to be within the specified age range, asking if they would like to visit a robot exhibit. Once the study was explained to their parents and informed consent was obtained, the researcher accompanied individual children into the robot exhibit. The response rate was about 95%. The experiment was conducted every day of one week in the summer of 2009. It was approved by the university's Conjoint Health Research Ethics Board. Most children in this study also participated in another project on children's helping behaviors towards a robot (Beran et al., 2011). We found no significant differences in perceptions of animism across the conditions used in the helping study or any relationship with helping behaviors.

2.1.1. Description of experiment

Once inside the booth, which was enclosed by a heavy curtain, children were seated in front of a robot (see Fig. 1). The robot, which was turned on and ready to execute a number of commands issued by a researcher, was on a platform at about the height of the child. The self-contained electric D.C. servo driven robotic arm used was a CRS-Plus small 5 degree of freedom articulated arm having a base ($\pm 175^\circ$ rotation), shoulder ($+110^\circ$, 0° rotation), upper (0°, -130° rotation) and lower arm ($\pm 115^\circ$ rotation), and wrist ($\pm 180^\circ$ rotation) motions controlled by a RSC-M1A robot system controller executing a sequence of pre-defined motions via a coded program. The robot joints included optical encoders for position feedback and could move at speeds of 180°/s. As with any robot of this type, it made a low humming noise when it moved, which was barely audible at the science center due to white noise created by an overhead fan. The robot's speed was limited (both program and hardware) to slower speeds to prevent personal injury. With the used joint speeds the robot had the capability of moving a 2 kg payload, although only objects weighing a few grams (i.e., small rectangular wood pieces) were used. For added safety, children were positioned outside of the 3D workspace of the robot (i.e., 0.56 m) at all times. The robotic arm was covered in craft foam and corrugated plastic to appear pleasing to look at. Gender neutral colors yellow, white, and black were chosen. The end of the arm was covered with a head that contained two eyes made of smooth silver buttons. The grip at the end of the arm was situated in the mouth of the head. Thus, the robot appeared to pick up blocks with its mouth. The robot stacked six blocks into two towers each with three blocks. It stacked one block at a time, which took about two minutes. After it stacked each block it moved upwards so that its face was directly opposite the child's face, thus, appearing to be looking at the child. In addition, it was programmed to drop the last block and seemed to drop it accidentally. It then opened its mouth and moved back and forth over the platform as if looking for the block. After 25 s it returned to the center position opposite the child's face and stopped. Thus, it was programmed to exhibit autonomy as a robot rather than merely a machine. These programs were hard coded and no artificial intelligence mechanisms were used when running the robot. Thus, the robot did not perform any form of decision based on its interaction with the world (e.g., had no form of intelligence). The robot was switched on and ready to execute commands at all times. Thus, it was assumed children knew it was switched on because it moved and executed the described tasks.

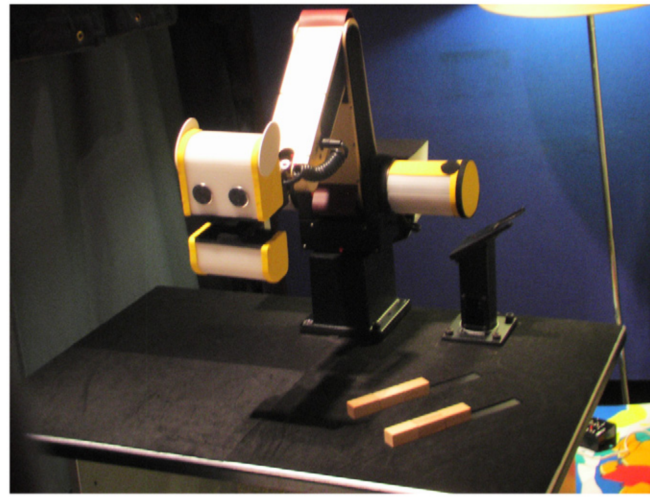

Fig. 1. Five degree of freedom robot arm on platform with blocks.

In the test exhibit there was an adjoining space behind a divider used to situate two laptops. One of these, directly connected to the robot, issued the commands to control the robotic arm including a stop button, which could be used as an emergency stop, via a serial communication port. The second laptop was connected to a camera mounted on the wall behind and to the side of the robot and facing the child.

In sum, the sequence of events was as follows. The researcher seated the child in front of the robot, then went behind the divider and started sending commands to the robot, which executed the desired task. Once it finished stacking the blocks, the researcher returned to the child and conducted an interview. Children were then thanked and guided back to their families.

2.2. Measure

Nine questions were asked during the semi-structured interview, over a 5–10 min duration. Section 1 consisted of three questions asking children to provide a general description of the robot (e.g., "Do you think the robot is a boy or girl?[1] What name should we give the robot? What do you think of the robot?"). Section 2 included six questions about the robot's characteristics (Melson et al., 2009). Cognitive questions included: "If you saw the robot again, could the robot remember you?", and "Does the robot know how you are feeling?" Affective questions were, "Does the robot like you?", and "If a friend came over and you were playing with your friend, would the robot feel left out?" Behavioral questions consisted of: "Can the robot see the blocks?", and "Can the robot play with you?" Responses of "yes" or "no" to each question were followed with an open-ended query, "Why?" or "Why not?" These responses were written verbatim.

3. Results

3.1. General description of the robot

In total, 72.8% ($n=134$) of children considered the robot to be male, 15.8% ($n=29$) regarded the robot as female, one child stated the robot was neither, and 10.9% ($n=20$) did not know. Sex of children was not related to whether the robot was described as male or female, $X^2(1)=0.93$, $p>0.05$.

Names children provided for the robot were coded as human (e.g., 'Bob', 'Rick', 33.7%, $n=62$), machine (e.g., 'The Stacker', 'Zoby', 37.5%, $n=69$), animal (e.g., 'Spud', 'Fizzy', 4.3%, $n=8$), or a combined human–machine type name ('Mr. Robot', 3.3%, $n=6$). The criteria used in this study to classify the names were based upon the familiarity of typical names for people and pets. Those names that fit neither category were specified as machine. Another 39 children (21.2%) did not know what to name the robot. The intraclass correlation as measured by Cohen's Kappa for two raters, who were researchers on this project, was 0.98 suggesting very good inter-rater reliability for type of name coded.

When asked about their general impressions of what they thought of the robot, 88.0% ($n=162$) generated a positive description such as 'cool/awesome' ($n=96$), 'good/neat' ($n=41$), they like the robot ($n=10$), nice ($n=5$), interesting ($n=4$), smart ($n=2$), realistic ($n=1$), super ($n=1$), fascinating ($n=1$), and funny ($n=1$). Two children reported that the robot had a frightening appearance, and three children thought it looked like a dog. Another 12 children provided a response that did not seem to address the question (e.g., "Yeah robot", "I'm making one"), and 5 children did not provide a response.

3.2. Robot's characteristics

The number of children responding to the presence or absence of each cognitive, affective, and behavioral characteristic is shown in the following three tables. The number of children who responded "yes" to each question is listed first, followed by the number of children providing each type of explanation about why the robot possesses these characteristics. Content analysis was conducted to code these explanations. Responses were first reviewed by one of the researchers to develop themes. Then this person and another researcher on the project used these themes to code each response as suggested in Richards (2005). Cohen's Kappa coefficients ranged from 0.87 to 0.98, with a mean of 0.96 indicating very good inter-rater agreement. The number of children who responded "no" to each question and the coding of their explanations are next presented in all tables. Finally, the number of children who could not supply an answer as to whether the robot possessed each type of characteristic is shown at the bottom of the tables as "Do not know".

3.2.1. Cognitive

As shown in Table 1, more than half of the children (52.7%) stated the robot could remember them if they saw it in the future. This is significantly higher than the proportion of children who stated it would not (37.0%), $p<0.05$. Of these children, 39 commented on human abilities including that the robot was able to see their face, hair, and clothes, and that the robot was smart and had a brain. Another 16 children provided a mechanical reason by stating it had a memory chip, camera, or sensors, or may have been programmed.

Over a third of the children (37.0%) stated the robot could not remember them, with 33 children commenting on its human features (no brain, eyes, or memory) and that the robot did not like them. Also, 14 children provided a memory limitation such that there were too many people visiting the science center, making it difficult for the robot to remember them. In total, 19 children provided a conditional response: 9 stated the robot's memory depended on whether the robot had a brain, 7 stated it depended on the duration of time the child was away from the robot, and 3 stated it depended on whether the robot was programmed. About 10% of the children stated they did not know if the robot could remember them, and 35 children did not know why they thought the robot could or could not remember them (24 children in the 'yes' group and 11 children in the 'no' group). A total of nine

[1]This question does not offer the response of "neither", which is considered in the discussion section.

Table 1
Number and percentage of children reporting cognitive features of robot ($N=184$).

Robot can remember you		Robot knows your feelings	
Yes	97 (52.7%)	Yes	54 (29.3%)
Can see me	37	Can see me	18
Has memory chip, sensors	15	Has memory chip, sensors	5
Smart, has brain	3	Smart, has brain	3
If has a brain	6	Do not know why	17
If short duration	5	Not coded	11
If programmed	1		
Do not know why	24		
Not coded	6		
No	68 (37.0%)	No	103 (56.0%)
No brain, eyes, or memory	30	No brain, eyes, or memory	37
Too many people to remember	14	No interaction with me	19
Robot does not like me	3	If not programmed	8
If no brain	3	Do not know why	31
If long duration	2	Not coded	8
If not programmed	2		
Do not know why	11		
Not coded	3		
Do not know	19 (10.3%)	Do not know	27 (14.7%)

responses (6 in the 'yes' group and 3 in the 'no' group) did not seem to provide a reason for their answer and so were not coded (e.g., "Doesn't feel like it would").

Also shown in Table 1 are the children's perceptions about the robot's knowledge of their feelings. More than a quarter of the children (29.3%) thought the robot had this capability, which is significantly lower than those who responded negatively to this question, $p<0.05$. A total of 21 children stated the robot had human characteristics including vision (e.g., "He can see me") and intelligence (e.g., "He's smart") to be able to know their feelings, and 5 children commented on its mechanical features. Over half of the children (56.0%) did not believe the robot had knowledge about feelings, with the majority of them stating it was for lack of human features. Another 19 children stated they did not have enough opportunity to interact with the robot for it to detect their feelings. Many children did not know if the robot knew their feelings, another 48 children (17 children in the 'yes' group and 31 children in the 'no' group) could not provide a reason for their perceptions about the robot's feelings, and 19 children (11 children in the 'yes' group and 8 children in the 'no' group) gave a response that did not answer the question (e.g., "Researchers need to find that out more").

To determine age differences in beliefs about the cognitive characteristics of the robot, we conducted a chi square analysis for each question about whether children thought the robot could remember them and knew their feelings. We classified children into two groups according to whether they were below age 12 years ($n=166$), or 12 years or older ($n=18$). A larger percentage of the younger children (62.8%), compared to older children (23.5%) thought the robot could remember them, $X^2(1)=7.79$, $p<0.01$, $\Phi=0.24$. Similarly, younger children (38.6%), compared to older children (5.6%) were more likely to report that the robot knew their feelings, $X^2(1)=7.66$, $p<0.01$, $\Phi=0.22$.

3.2.2. *Affective*

Regarding affective characteristics, the majority of children (64.0%) reported that the robot liked them, which is significantly higher than the number of children who did not, $p<0.05$ (see Table 2). The primary reason for this belief was that they thought the robot was friendly towards them, either by smiling or looking at them. Nine children indicated the robot had positive intentions including trying hard to and teaching them to stack the blocks. The absence of negative characteristics was another reason given for thinking the robot liked them (e.g., "The robot didn't hurt me and was not mean to me"). Another 20 children considered how their own behaviors such as liking and smiling at the robot led them to believe that the robot liked them. Some children (8.7%) believed that the robot did not like them with most of them stating it was because they thought the robot did not allow them to stack blocks. Only 4 children stated the robot was not capable of experiencing thoughts or feelings about liking someone. A large number of children did not know if the robot liked them ($n=50$), could not explain why they thought the robot liked or did not like them ($n=35$, 33 children in 'yes' group and 2 children in 'no' group), or provided a response that did not address the question ($n=5$, e.g., "Yes. It's crazy. It stacks up a lot of blocks—like 100").

Similarly, the majority of children (69.0%) reported that they thought the robot would feel left out if they played with a friend, which is also significantly higher than the number of children who thought it would not, $p<0.05$. Most of these children explained that the robot would have no one to play with (e.g., "We're not playing with him"). Many children ($n=36$) identified hurt feelings for the robot

Table 2
Number and percentage of children reporting affective features of robot ($N=184$).

Robot likes you		Robot feels left out	
Yes	118 (64.0%)	Yes	127 (69.0%)
Looks/smiles at me, friendly	38	No one to play with	62
I was nice/did something nice	20	Hurt feelings	36
Did not hurt me	13	I would include robot	9
It had positive intentions	9	Not fair	2
Do not know why	33	Do not know why	11
Not coded	5	Not coded	7
No	16 (8.7%)	No	53 (28.8%)
Ignored me/didn't let me help	10	No thoughts/feelings	29
No thoughts/feelings	4	Would include robot	16
Do not know why	2	Does not understand	3
Not coded	0	Do not know why	5
		Not coded	0
Do not know	50 (27.3%)	Do not know	4 (2.2%)

Table 3
Number and percentage of children reporting behavioral features of robot ($N=184$).

Robot sees blocks		Robot plays with you[a]	
Yes	77 (41.8%)	Yes	154 (83.7%)
Has eyes	32	Construction	103
Stacking	20	Ball game	26
Sensors, camera	13	Running game	12
Trained	5	Board game	12
Other	0	Other	17
Do not know why	7	Do not know why	5
Not coded	0	Not coded	5
No	94 (51.1%)	No	25 (13.6%)
Eyes not real	49	Physical limitation	11
Sensors, camera	19	Other	4
Missed a block	19	Do not know why	6
Guessed	1	Not coded	4
Do not know why	5		
Not coded	1		
Do not know	13 (7.1%)	Do not know	5 (2.7%)

[a]Many children provided more than one response.

in this situation including sadness, jealousy, and rejection. Another nine children stated they would include the robot, and two stated that not including the robot is unfair. Over a quarter of the children stated the robot would not feel left out, with 16 of them stating that they would include the robot. Thus, they would not allow the robot to be left out of their play. About half of the children who stated the robot would not feel left out provided the explanation that it does not have thoughts or feelings. Also, some children did not know if the robot would feel excluded ($n=4$), could not explain their response ($n=16$, 11 children in 'yes' group and 5 children in 'no' group), or provided a response that did not address the question ($n=7$, e.g., "a bit").

Chi square analysis was then conducted to examine age differences in beliefs about the affective characteristics of the robot. The proportion of children younger than age 12 years (87.6%) who believed the robot liked them is similar to that of older children (92.3%), $X^2(1)=0.25$, $p>0.05$. Younger children (72.8%), however, were more likely to believe that the robot would feel left out than did older children (50.0%), $X^2(1)=4.07$, $p<0.05$, $\Phi=0.15$.

3.2.3. Behavioral

Regarding its behavioral characteristics (see Table 3), more than a third of the children stated the robot was able to see the blocks, which was similar to the number of children who did not, $p>0.05$. Most of the children who responded affirmatively stated that the robot could see with its eyes (although no computer vision mechanisms were used in controlling the robot). Some children ($n=13$) stated it had mechanical features that allowed it to see the blocks. Other children stated it was able to see the blocks because it could stack them, or that it was trained to find them. Just over half of the children (51.1%) thought the robot could not see the blocks, with the majority of them stating that the robot's eyes were not real (e.g., "Eyes don't think"). Other explanations given include mechanical construction of robot (e.g., "Robot has sensors to pick up blocks", $n=19$), the fact that the robot dropped the last block and could not find it ($n=19$), and guessing ($n=1$). Also, some children did not know if the robot could see the blocks ($n=13$), could not explain their response ($n=12$, 7 children in 'yes' group and 5 children in 'no' group), or provided a response that did not address the question ($n=1$, "seems to").

The majority of children (83.7%) stated the robot could play with them, and this is significantly higher than the number of children who stated that it could not, $p<0.05$. Children provided a variety of ideas for play. Most of them ($n=103$) stated that it could play a construction game such as blocks building, speed stacking, or Lego®. Many children stated it could play an activity with a ball (e.g., soccer, fetch, catch). Some identified a running game (e.g., hide-and-seek, tag), and a board game such as puzzles or tic-tac-toe. A variety of other activities were suggested, for example, a card or other hand game, coloring, video games, and riding on the robot, having the robot do tasks for them such as cleaning their room, and teaching it things. Of those children (13.6%) who stated that the robot could not play, 11 children stated it was because of physical limitations including no mobility or hands. Another four children stated that the robot was weird or not real, it could break, or they had no interest in playing with it. Finally, some children (2.7%) did not know if it could play, could not explain their response ($n=11$, 5 children in 'yes' group and 6 children in 'no' group), or provided a response that did not address the question ($n=9$, "play with the robot").

Chi square analysis was then conducted to examine age differences in beliefs about the behavior characteristics of the robot. The proportion of children younger than age 12 years (46.4%) who believed the robot could see them is similar to that of older children (38.9%), $X^2(1)=0.37$, $p>0.05$. Also, the proportion of younger children (85.2%) who believed the robot could play was similar to that of older children (88.9%), $X^2(1)=0.18$, $p>0.05$.

To further determine whether children considered the robot to be animate or inanimate, we conducted a discourse analysis by examining the pronouns children used in reference to the robot. A total of 38 children (20.7%) referred to the robot as "it" in their responses, 42 (22.8%) stated "he", and 95 children (51.6%) used both. The pronouns were not audible for another 9 children (4.9%). We then conducted a chi square analysis to see if the male pronoun was used more often by boys (or girls). The result was not significant, $X^2(2)=1.16$, $p>0.05$. We also examined whether pronoun usage was related to gender assigned to the robot. This result was neither significant, $X^2(2)=3.22$, $p>0.05$.

4. Discussion

The present study examined children's animistic impressions of a robot[2] outside of a lab and in a museum setting that allowed children to express a visceral reaction, thereby reducing prescribed or socially desirable behavior (Weiss et al., 2009). Results show that many human characteristics were adopted. Regarding its cognition, 52.7% of the children stated it would remember them, but fewer children 29.3% thought it knew how they were feeling (compared to 56% who thought it did not). Affective characteristics were highly endorsed. About 64% stated that the robot liked them and 69% said that it would feel left out if not played with. In their behavioral descriptions, 41.8% of the children thought it could see the blocks (but 51% stated it could not), and 83.7% of them thought the robot could play with them. It is evident that children assigned many animistic abilities to the robot, but were more likely to ascribe affective than cognitive or behavioral ones. There was additional evidence of human qualities according to the names children gave it, their descriptions of it, and the pronouns they used to reference it in their responses. These animistic responses, moreover, were more apparent in younger than older children.

4.1. Cognition

In regards to cognition, of those children who believed that the robot had recognition memory, 38% explained that the robot was able to see their face, hair, clothes, etc. Similarly, 33% provided this reason for the robot's ability to recognize their feelings. This suggests that they considered it to possess a human-like anatomy (e.g., eyes and a brain) enabling it to see and recognize their physical features and emotions. Gaining recognition of their physical features to store into long-term memory, according to these children, seemed possible for a robot. Fewer children (15% of those who thought the robot would remember them and 9% of those who thought the robot knew their feelings) stated that this ability was conditional of how the robot was built, thus, suggesting that although a human quality, robots can mechanically perform this function as well. Moreover, 16 children believed that the ability for memory and 5 children believed that knowledge of feelings were based on mechanical reasons. Rather than representing animistic responses, these may suggest belief in programming and design abilities. Nevertheless, if these responses are disregarded, a large proportion of children (44%) believing in the human capability of memory remains. Similarly, by removing the mechanical explanations for the ability to know feelings 27% of children are found to hold this belief. Thus, children are more likely to believe in the cognitive ability of memory than knowledge of feelings. It seems reasonable that fewer children believed that the robot knew their feelings, given that this is a complex task. This result is similar to Melson et al.'s (2005) finding that 22% of children thought a robotic dog knew how they were feeling. In the present study, children who thought the robot did not have this capability may consciously or intuitively recognize that identifying emotions is a complex skill. According to Saarni (1999), it requires interpreting meanings of expressions, understanding contextual cues to emotions, recognizing that others have intentions,

[2]Fewer than 2% of children thought the robot looked like an animal.

comprehending that others are separate beings, and developing vocabulary for various emotions.

4.2. Affect

Surprisingly, more children considered the robot capable of emotions than cognition and behaviors. Indeed, positive affect was endorsed by 64% of children, such as fondness towards them, and negative affect was endorsed by 69% of children, in the form of rejection. This result is comparable to Melson et al.'s (2005) finding that 74% of children thought a robotic dog could experience happiness and Weiss et al.'s (2009) finding that 87% stated it could experience sadness. Many children (32%) ascribed the positive affection from the robot to its facial features (seemed to smile and look at the child) and to its movement (head of robot realigned to child's face when moving blocks, giving the impression of 'looking' at the child). In fact, the beginning position of the robot's head was in alignment with the child, and returned to this position seven times throughout the block stacking task giving the appearance of frequent eye contact. According to Marsh (1988), frequent eye contact suggests a high degree of interest in a person, honesty, and willingness to take turns. Children may, thus, have experienced a sense of affection from the robot. Indeed, eye contact has been found to be an important human characteristic of robots to encourage infant engagement (Itakura et al., 2008). Also, 7% of children made assumptions that the robot had positive intentions, an example of an animistic belief, and, therefore, liked them. Absence of harm and children's own kind actions towards it, led 11% and 17% of children, respectively, to believe that the robot must like them. It is possible that they were projecting their own positive feelings onto the robot. Indeed, Turkle (1995) suggested that even after minimal interaction with a robot, children transfer their own understanding and experiences onto even a relatively unsophisticated robot.

In terms of its negative affect, 69% of children believed that the robot would feel rejected and lonely if not included in play. They may, again, have been projecting their own experiences of rejection in these circumstances and attributing these emotions to the robot as well. In fact, these feelings may be particularly salient and debilitating (Parker et al., 1995).

4.3. Behavior

Children's perceptions about two behavioral characteristics of the robot were also examined. Fewer children (41.8%) responded affirmatively to the robot seeing the blocks (compared to 51.1% who responded negatively), whereas more children (83.7%) indicated that robot was capable of play (compared to 13.6% who did not). Regarding its looking behaviors, almost half of these children (41%) believed it was capable because it had eyes. These eyes were made of silver buttons. Perhaps children perceived these simulated eyes as creating a sense of intimacy or interest in them (Kleinke, 1986). Indeed researchers suggest that children are born with a preference for eye contact (Batki et al., 2000; Farroni et al., 2002). Although not technologically sophisticated, the eyes were shiny and reflected a small amount of light. This may have created an illusion of movement or sensing ability. Also, 26% of children ascertained visual abilities to the movement of the robot over the blocks. It was programmed to sweep back and forth over the blocks to appear as if it was 'looking' for the last one. Thus, they seemed to recognize this as a human-like characteristic. A few children (6%) also believed it was 'trained' to look for blocks. Although this learning would at first require an external agent, the robot would, thereafter, have its own ability to look for the blocks. A total of 13 children believed the robot had vision capabilities due to mechanical reasons. If this non-animistic explanation is removed then a remaining 35% of children believed that the robot had the human capability of vision.

Finally, 83.7% of children thought the robot was capable of playing a variety of games. This percentage is remarkably similar to studies with robotic dogs (Melson et al., 2005; Weiss et al., 2009). The most commonly reported type of game in our study was construction with blocks, likely because children witnessed it perform this action. Additional suggestions included activities requiring more skills and coordination, as well as features that the robot clearly did not possess (e.g., legs for running). Children may have projected their interests combined with their enthusiasm to interact with the robot in response to our question about whether the robot could play with them. The fact that so many children in our study proposed means of play for the robot suggests that they are willing to invite robots into their world of creativity, imagination, role development, social–emotional expression, and simple fun, which play is known to provide (Pellegrini and Smith, 1998; Shonkoff and Phillips, 2000; Tamis-LeMonda et al., 2004).

In addition to children's answers to the questions about the robot's characteristics, animism was evidenced in three ways. The majority of children (88.6%) assigned a gender to the robot, with only one child stating it was neither. However, since this latter response was not provided as an option, children may not have considered it. Future research should include this as a choice in the responses. A total of 72.8% of the children (both male and female) considered the robot to be male, which is similar to children's assignment of male gender to robots in stories (Bumby and Dautenhahn, 1999). Walters et al. (2008) also found that adults are more likely to assign a male than a female name to a robot. Perhaps the design of the robot made it appear male, or robots in popular media are often depicted as male (e.g., WALL-E, RoboCop, Star Trek's Data). It is also possible that the activity of stacking blocks, a visual-spatial task that boys may perform better than girls (Loring-Meier and Halpern, 1999), creates a gender stereotype that the robot is male. Further evidence of animism is given by the names children provided for the robot with 33.7% of them human. Moreover, 22.8% of the participants referred to the robot with the gendered pronoun, ‘‘he’’ when talking about it. The use of this pronoun is consistent with the finding that 72.8% of children assigned a male gender to the robot. Indeed, no children used the pronoun ‘‘she’’. Although some machines such as cars and boats are known to be referred to as ‘‘she’’ in Canadian and American culture, this was not the case when children referenced the robot. In Carpenter et al.’s (2009) study of robots for domestic use, they found anecdotal evidence that adults prefer a robot with a female rather than a male appearance. Perhaps the context in which the robot is presented influences people's preferences for a specific gender representation.

Why did so many children ascribe human characteristics to our robot? Perhaps children held little knowledge about the mechanics of robots, thus, relying on their existing knowledge state pertaining to humans. Certainly, some children would have not possessed the vocabulary or understanding of robotics causing them to rely on words from our questions like ‘remember’, ‘know’, ‘like’, ‘feel’, ‘see’, and ‘play’ that express human-like characteristics. Indeed, Weiss et al. (2008) found that although children provided imaginative and inventive concepts about *what* robots can do, they lack this creativity and insight of *how* the robots can do it. For many children, therefore, robots may function ‘‘magically’’. It is also possible that they project their understanding of human nature onto a technological device and assume that it ‘operates’ the same way they do. If children (perhaps subconsciously) consider the robot as a mirror of their own schemata, perhaps they are not ascribing human characteristics to the robot at all. Children may have seen the robot as an extension of themselves, possessing similar abilities. and sharing similar experiences. In Piaget’s own theoretical terms, children may be assimilating their new experience with the robot with their existing schemata of themselves and their world. Perhaps in the future, as robots become more commonplace and children have more opportunities for interaction, their schemata of the living world may need to accommodate (re-organize) to appreciate how robots are similar and dissimilar to humans. Indeed, Kahn et al. (2006) describe this change as the development of ‘‘a new technological genre’’. These ways of thinking, moreover, are likely to transform as do the robots they are modeled after.

Another explanation is the autonomous action our robot exhibited. Researchers have indeed shown that animism is apparent for objects that move independently (Gelman, 1990; Gelman and Gottfried, 1996; Poulin-Dubois and Schultz, 1990). It is suggested that the movement of the object may give the observer the impression that it is in control of its actions, which is a human quality (Tremoulet and Feldman, 2000). Applied to children’s understanding, it can be explained simply as: if the robot moves by itself, then it must have intentions and goals.

As robots are built to become more anthropomorphic, the distinction between biological and technological nature becomes uncertain. This may explain why a significant number of children did not respond to questions about whether the robot possessed various human-type characteristics or could not provide explanations for these characteristics. Their ambiguity may be a result of the human appearance (e.g., eyes, mouth, head) of the robot and its performance of a function that children are familiar with (i.e., stacking blocks), combined with some awareness that the robot is similar to and yet different than humans. Moreover, Abelson (1981) suggests that people’s own cognitive–affective–behavioral schemata are not always readily conscious, and, thus, may be difficult to identify through self-report methods. It is not surprising, therefore, that so many children in our study did not respond to questions about the robot’s cognitive, affective, and behavioral characteristics. Furthermore, this limited awareness may explain why knowledge about feelings and vision were less likely to be considered abilities the robot is capable of. Indeed, children readily experience emotions but not specifically label them, just as they likely rely on vision but not consciously acknowledge it.

4.4. Animism and age

Consistent with Piaget’s (1929, 1930, 1951) discovery that young children assign life-like qualities to inanimate objects, we found that children younger than age 12 years were more likely than children 12 years and older to believe that the robot possessed several human attributes. Specifically, the former was significantly more likely to assign cognitive beliefs to the robot by stating that the robot would remember them (62.8% compared to 23.5%), and knew their feelings (38.6% compared to 5.6%). Regarding affect characteristics, younger children were more likely to believe that the robot would feel rejected (72.8% compared to 50.0%) but were similar to older children in reporting that the robot liked them (87.6% compared to 92.3%). Behavioral characteristics including the ability to see (46.4% compared to 38.9%) and play did not differ between younger and older children (85.2% compared to 88.9%). These combined results provide mixed support for Piaget’s supposition that animism is non-existent when children move into the formal operation stage at age 12 years. They are consistent, however, with the many studies that neither support this age difference (Golinkoff et al., 1984; Gelman et al., 1983; Keil, 1979). We could not determine more precisely the age at which animism towards robots tends to decrease due to the low number of children ages 12 years and older. Nevertheless, our study does reveal that older children were *not* more likely to ascribe animistic qualities to a robot.

4.5. Limitations

Although our exploratory study provided many new insights into children’s understanding of robots, it is not without its limitations. All children who participated in the study were visitors at a local science center. Thus, they may possess unique characteristics compared to non-visitors, which may limit the generalizability of our results. Children may also have demonstrated elevated mood towards the robot by virtue of the exciting environment around the robot exhibit, which may have affected their thoughts about the robot. Thus, our results need to be replicated by visits with a robot in other settings. Also, children in our study observed the robot stacking blocks. It is possible that children's responses are partly dependent on the appearance and actions of the particular robot that was used. Thus, in addition to setting, replication with other types of robots would strengthen our findings. Perhaps another limitation to our results is that our initial questions about the name and gender of the robot may have engaged children in a pretend game that invited make believe responses about its human qualities. Moreover, our questions used terms such as "seeing" and "feeling", which may have led children to believe that the robot possessed these human abilities. Also, for some children, the order of the questions may have influenced responses. For example, three children stated that the robot would not remember them because they believed that the robot did not like them. The question about being liked was asked before this question and may have triggered this explanation. It is recommended that future studies alter the order of these types of questions and consider alternate phrasing. An advantage of our study was that we did not use the term 'alive' as did Piaget, which researchers have shown that children may misconstrue (Huang and Lee, 1945). Moreover, we cannot infer that children believed the robot was alive based on their verbal responses to human-type characteristics given studies showing that while a robot may appear to demonstrate psychological characteristics, they are not necessarily judged as possessing biological characteristics (van Duuren and Scaife, 1996; Jipson and Gelman, 2007; Kahn et al., 2006).

4.6. Implications for robot design

The fact that so many children ascribed life characteristics to the robot suggests that they have high expectations of them. This presents a challenge to robot designers to match these expectations, if the purpose of the robot is to garner and maintain interest from children. We do not believe, specifically based on our results, that it is important to design robots that children want to engage with. Rather, we recognize that this is one possible development in the future.

Indeed, Weiss et al. (2009) observed that children showed negative reactions when a dog did not respond to their initiations. These authors further report, however, that children seemed to persevere in their interactions when the robotic pet "did not fulfill their expectations" (p. 246). This suggests that children may realize that living objects do not always respond the same way to their initiations (e.g., a dog may not always come when called, but may come if a biscuit is offered). Therefore, to increase child engagement with a robot, it may not be necessary that it demonstrate perfect consistency in response to the child's initiations. Of course, children may become discouraged if the robot's response is erratic. Instead, we propose that a high, but not perfectly predictable response to the child's behaviors will lead to the longest and most interesting interactions a child may have with it. This may be a more realistic representation of how living objects respond to children.

We also offer that children's propensity to believe that the robot was capable of possessing many human characteristics, indicates that children *want* the robot to be capable of these abilities. Children themselves seem predisposed to curiously explore and interact with new objects such as robots. In fact, they seem "programmed" to interact positively with them, which is exemplified in our finding that 83.7% of children believed the robot could play with them in a variety of ways. This suggests that robots need to be multifunctional and versatile. Perhaps as apps can be downloaded to communications devices to maintain user interest and provide useful tools, apps can be uploaded to robots to match children's developing needs and interests.

In conclusion, this study presents a cognitive-affective-behavioral model to demonstrate that children are likely to believe in some animistic characteristics. These include memory, emotions, and physical play, but are less likely to include vision and knowledge of feelings. This suggests that each animistic belief must be examined separately rather than as representing cognition, affect, or behavior as a whole. Furthermore, we found some evidence of age differences with children younger than age 12 years more likely to assign cognitive abilities, and negative affect, but not more likely to believe the robot liked them, or had behavior characteristics. This further supports the argument for examining animistic beliefs separately. Thus, although the schemata model is useful in organizing various animistic beliefs, endorsement of a belief of one type of characteristic does not necessitate endorsement of another belief in another.

With researchers programming robots to detect and respond to affective states in children through physiological sensing such as cardiovascular and electrodermal activity (Liu et al., 2008), children's perceptions of human characteristics in our robot may not be 'flawed'. Applications to daily routines seem limitless: It will become our challenge not to think that robots are not alive, but to discern which robots indeed are!

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