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5 **YOUNG CHILDREN’S UNDERSTANDING OF ANIMACY
 AND ENTERTAINMENT ROBOTS**

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19 Complex interactions, biologically-inspired features and intelligence are increasingly seen
 in entertainment robots. Do these features affect how children interpret robots? Children
 21 have “animistic intuitions” that they use to attribute intelligence, biology, and agency to
 living things. Two studies explore whether young children also apply animistic intuitions
 23 to robotic animals, and whether attributes vary by the child’s age, robot behavior and
 appearance. A total of ninety-three three- to five-year-olds participated in two experi-
 25 ments. They observed or interacted with robots that exhibited different behaviors and
 levels of responsiveness to their environment. They then answered simple questions that
 27 probed their attributions of biology, intelligence, and agency. The results indicated that
 regardless of the robots’ look and behavior, younger children over-generalized their ani-
 29 mistic intuitions about real animals and older children attributed some animistic qualities
 but not others. One implication is that young children’s criteria and attributions do not
 depend on robot features that are important for older children and adults. Another impli-
 31 cation is that children do not have a theory of aliveness, and they develop the category
 of robot slowly and piecemeal as they learn discrete facts about how technology differs
 33 from living things.

35 *Keywords:* Young children; human–robot interaction; robotic pets; social responses to
 technology; cognitive psychology; conceptual development; naïve theories.

37 **1. Introduction**

39 Entertainment robots are rapidly increasing the degree to which they can mimic the
 behavior of living beings. Robotic dogs for example, can recognize their name, they
 41 can spot a ball and approach it, and they can dance to music. If we set aside the
 goal of improving robot technology, a central assumption of entertainment robots
 appears to be that their increased realism will have important practical benefits.
 Many hope to see robots as social companions for elderly populations and for those

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1 with special needs.^{1–4} Entertainment robots are entering the home, and more bio-
logically inspired robots are replicating live animals.⁵ These new applications raise
3 the question of whether realism makes a practical difference. Robots are boundary
objects that include some qualities of living things, but not others. It has become
5 an important question whether realistic features make a difference in the feelings
and behaviors they elicit from people^{6,7} and how people integrate robots into their
7 everyday experience.⁸

Entertainment robots are also being designed for children in the long-term hope
9 that biologically-inspired technologies may eventually serve as pets and become
sources of comfort and learning. Children, however, differ from adults in many
11 ways, and relatively little research exists on how children interpret these “boundary
objects”⁹ or how such advanced technologies can assist children in their learning
13 and development.^{10,11} The purpose of the current work is to explore what young
children think about entertainment robots. This has some practical importance,
15 because the findings can tell us whether it is possible to use advanced technologies
to get children to treat robots in similar ways to live pets. It also has some theoretical
17 importance, because it can clarify how children come to understand artifacts that
stretch the limits of their existing beliefs about what it means to be alive.

19 **2. Research on Children’s Attributions of Animate**

In the following two studies, children evaluated the animate qualities of robotic
21 dogs. We wanted to find out if young children confer robotic dogs with the prop-
erties of living dogs. To know whether children treat robotic dogs as living, it is
23 necessary to understand how children view living things generally. To adults, living
dogs have a cluster of animate properties that include relatively intelligent behav-
25 iors (e.g. locate a bone), biological properties (e.g. grow), plus the agency to take
independent initiative (e.g. run away). Young children also have “animistic intu-
27 itions” that they use to attribute intelligence, biology, and agency. For example,
research has shown that infants are quite precocious at distinguishing biological
29 and non-biological movements¹² and can differentiate goal-directed behaviors from
random movements.^{13,14} It is somewhat controversial, however, how these differ-
31 ent intuitions become integrated into a concept of animate or living. Carey,¹⁵ for
example, argues that children do not achieve an integrated concept of alive until
33 middle school. In contrast, Inagaki and Hatano¹⁶ found that five-year-old children
make the living/nonliving distinction and believe that animals and plants are both
35 alive. The authors proposed that children have an intuitive theory of “vital powers,”
whereby living things need food to sustain their powers of growth.

In general, there have been two stories for how children’s concept of animate
37 develops. The “theory” story proposes that children have a coherent body of knowl-
edge with some generality and that these bodies of knowledge evolve with matu-
39 ration. This approach views the child as a theory builder, and it argues that there
are concepts that cannot be learned, and therefore, they must be innate (e.g. the
41

1 very concept of a goal; the belief that other people have minds). Gopnick and
2 Meltzoff,¹⁷ for example, propose that children are equipped with innate theories
3 that they start revising as early as birth. Children's theories mature as new the-
4 ories replace or transform old ones.¹⁸ Carey,¹⁵ for example, argues that children's
5 concept of animal evolves from a theory based on behavior to a theory based on
6 biology.

7 The second story proposes that children's acquisition of the concept of animate
8 is piecemeal.¹⁹ In this approach, children's ideas do not start with the coherent
9 texture of a theory. Instead, the children have pockets of poorly integrated facts
10 and beliefs. diSessa,²⁰ for example, proposes that people develop more coherent
11 physical knowledge by sorting through their "knowledge in pieces" and progressively
12 selecting the pieces that explain more of the facts.

13 Much of this debate has taken place in three domains; intelligence, biology,
14 and agency. A typical research paradigm involves showing children several different
15 objects that may perform different actions. The researchers then ask the children
16 probe questions to see what animate properties the children are willing to attribute
17 to the object. Gelman and Gottfried,²¹ for example, wanted to see if children make
18 the critical agency distinction between self-initiated movements versus externally
19 caused movements. Preschool children viewed animals and artifacts (e.g. a lizard,
20 a wind up toy) that were transported by a human hand. Children attributed the
21 movement to a person when the object was an artifact. In contrast, children said
22 the animal's movement was self-generated, even though they saw a hand move the
23 animal. Even three-year-old children make attributions in ways that indicate that
24 they believe that animate things have the agency to move on their own.²²

25 We adopted a similar research paradigm. We showed children different robots
26 that behaved in different ways. We then asked them probe questions about intel-
27 ligence, biology, and agency. Robots provide an interesting variation on the usual
28 paradigm, because they imitate features of animacy by design, but they are not
29 animate. By examining how children develop a new concept for robot, we may
30 be able to learn something about the "theory" versus "piecemeal" nature of their
31 knowledge of animacy.

3. Predictions about How Attributions of Animacy Develop

33 Our hypothesis is that young children do not have a coherent theory of animacy.
34 Rather, the properties of animacy are loosely coupled. One way to demonstrate this
35 hypothesis is to show that children will attribute different aspects of animacy at dif-
36 ferent frequencies. For example, children may attribute a high degree of intelligence
37 and biology, but not agency. Or, they may attribute some biological properties but
38 not others. Another way to demonstrate this hypothesis is to show that as children
39 get older, they reject some aspects of animacy for robots but not other ones. In
40 other words, they do not have a theory in the sense that their theory can be falsi-
41 fied if one of the necessary properties is not present. A third way to demonstrate

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1 that children lack a theory in any meaningful sense is to show that their “theoretical attributions” are not tied to data. For example, imagine a robot that shows
 3 extremely intelligent behavior by spotting a ball and then shows high agency by walking towards the ball and kicking it. Will this affect children’s attributions of
 5 intelligence and agency more than their attributions of biology? Or, is it the case that children do not have a theory that relates to evidence so much as an associative
 7 network of facts that tend to activate one another?

9 To reiterate our position, we assume that children learn to conceptually distinguish robotic animals from living animals by developing a new category of robot
 11 (or mechanical object) in piecemeal fashion. Our proposal is that “animate” is not a monolithic category, and therefore, the child does not learn in a single moment
 13 of insight that a robotic dog is not a living dog. Rather, we propose that children learn to exclude specific animate properties from the category of robot. For exam-
 15 ple, children may learn that things with hard plastic shells do not have certain animate properties (e.g. they do not grow). Because this is a discrete fact rather
 17 than necessary feature of any coherent body of knowledge, children are likely to maintain their other animistic attributions.

4. Study 1: Attribution Based on Watching

19 In the first study, children from three- to five-years-old watched three robots. One robot danced, another robot spotted a ball and kicked it, and a third robot did
 21 nothing. Afterwards we asked them the animacy questions shown in Table 1. We coded which robots the children pointed to as having the property or could perform
 23 the action mentioned in the probe question.

4.1. Method

25 *Participants.* Thirty-two children from a university day-care program participated. The children comprised three age groups: young ($n = 10$, $M = 43.5$ months, range
 27 35–44 months), middle ($n = 11$, $M = 52.5$ months, range 45–52 months), and old ($n = 11$, $M = 57.8$ months, range = 53–66 months).

Table 1. Questions for intelligence, biology and agency.

Questions: Do you think any of the dogs...? Which ones?	
Intelligence	1... can tell between a real and pretend bone?
	2... will remember me when I come back tomorrow?
	3... will know it's time to go for a walk if I grab a leash?
Biology	1... get hungry?
	2... ever grow?
	3... have a heart?
Agency	1... would try to wake you up in a fire?
	2... would jump onto the forbidden couch?
	3... would be able to do anything without the remote control?



Fig. 1. Children in Experiment 1 watched robots perform different actions.

1 *Design.* There were three robotic dogs as shown in Fig. 1 (Sony AIBO ERS-210,
 2 ERS-220A, ERS-311^a). There were also three behaviors the dogs could complete;
 3 *kick, dance, stand still.* For the *kick* behavior, the robot oriented towards a ball
 4 placed in front of it and then kicked it. For the *dance* behavior, the robot danced
 5 to music. For the *stand still* behavior, the robot was turned off and did nothing.
 6 For each child, each dog performed only one of the behaviors. To avoid confounding
 7 a particular robot with a particular behavior, the behaviors were counter-balanced
 8 across the three dogs. For example, some children saw ERS-210 dance, whereas
 9 other children saw ERS-220A dance. After the dogs performed, children heard three
 10 classes of animacy probes: Intelligence, Biology, and Agency. For each class of ani-
 11 macy, children heard three separate questions. Table 1 shows the full set of nine
 12 questions. Children indicated which of the robots had the feature, or ability, men-
 13 tioned in the question. If a child indicated that a robot had the specific feature or
 14 ability, the robot behavior received a score of 1, and when the child did not refer to
 15 the robot, a score of 0 was given. All told, the factors created a fully crossed $3 \times 3 \times 3$
 16 design: age by robot behavior by class of animacy probe, with three questions for
 17 each animacy class.

18 *Procedure.* Children participated in a one-to-one 10–15 min videotaped session.
 19 Figure 2 indicates that each child saw the three robotic dogs perform their respective
 20 behaviors in succession, with order of behavior counter-balanced across children.
 21 The experimenter lifted a box, and the dog performed its behavior. The box was
 22 then lowered, and the experimenter revealed the next dog. Each box showed a
 23 picture of the dog on the outside to help children remember which dog was where.
 24 After children saw all three different robots perform their respective behaviors, they
 25 heard the animacy questions one at a time. For each question, children indicated
 which dog(s), if any, could do what the question proposed. They pointed to the

^aThe entertainment robots (Aibo ERS-210, 220A, 311) were generously donated for this research by Sony Entertainment of America, San Diego, CA.

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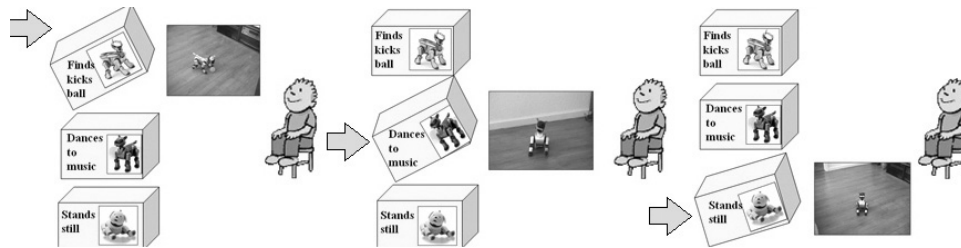


Fig. 2. Study 1 procedure for exposing children to the robots.

1 pictures of the robotic dogs. All children heard the questions in the same order, but
they were shuffled relative to Table 1.

3 **4.2. Results**

We first report the broader effects and then move to the effects of specific questions.
5 For each animacy class, children heard three questions. We found the total score for
each set of three questions for each dog. For example, for biology, if a child pointed
7 to the dancing dog for all three biology questions and pointed to the kicking dog for
only two of the questions, the dancing dog would receive a biology score of 3 and
9 the kicking dog would receive a score of 2. The behavior of the dog and scores it
received for each animacy class were crossed with the children's age in a multivariate
11 analysis of variance. In reporting the descriptive statistics, we use the more readily
understood percentages (i.e. 3 out of 3 appears as 100%).

13 There was no effect of age. Descriptively, the younger children were more
inclined to attribute animacy across all the questions (young = 74%, middle = 62%,
15 old = 64%), but the difference was not significant; $F(2, 29) = 0.82$, $MSE = 4.6$,
 $p > 0.4$. Figure 3 shows the mean percentages for the factors of behavior and animacy
17 class. There was a main effect of behavior on children's overall level of attribution;
 $F(2, 28) = 4.2$, Roy's Root = 0.298, $p < 0.05$. There was also a strong effect of
19 the class of animacy on children's attributions; $F(2, 28) = 16.5$, Roy's Root = 1.18,
 $p < 0.001$. There were no interactions.

21 *Post-hoc* analyses (using a Bonferroni adjustment for multiple tests) confirm the
patterns in Fig. 3. Children were significantly more likely to attribute animacy to
23 the *dance* behavior than *stand still* ($p < 0.05$), whereas the *kick* behavior was not
significantly different from the other two behaviors. Children were significantly more
25 likely to attribute intelligence to the robots than biology or agency ($ps < 0.01$).

27 Based on these analyses, the behavior of the robot influenced children's attribu-
tions of animacy, particularly the comparison of a motionless robot versus a dancing
robot. At the same time, the results make it clear that animacy attributions are
29 not monolithic, because the children were much more likely to attribute intelligence
than biology or agency (though children were still willing to attribute the latter
31 two properties over 50% of the time as well). Interestingly, the type of behavior

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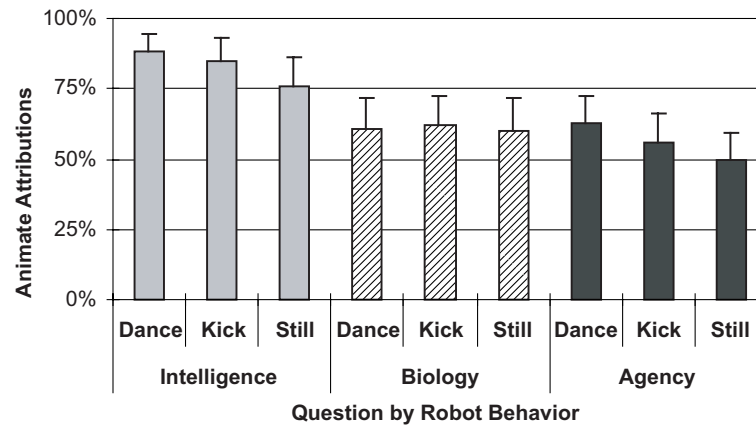


Fig. 3. Mean percentages for behavior and class of animacy.

1 did not influence the type of attribution. Children were not more likely to attribute
 intelligence to a robot that tracked down the ball and kicked it. Though the chil-
 3 dren differentiated types of animacy, these distinctions were not tied to particular
 behaviors.

5 The preceding analyses did not indicate any reliable effects of age. A more
 refined analysis shows an age effect. The following analyses examine how children
 7 responded to each of the questions within each animacy class. To simplify matters,
 the results for each animacy class are described in turn.

9 To examine intelligence attributions, the factors of age (3) by behavior (3) by
 intelligence question (3) were crossed in a multivariate analysis of variance.^b Figure 4
 11 shows the percentages of children who indicated the robots for each question broken
 down by age and animacy class. The figure does not indicate behavior because the
 13 behavior of the robots did not interact with age or question type.

The top panel of Fig. 4 shows the results for the intelligence questions. There
 15 were no effects of age, question type, or any interactions; $ps > 0.4$. There was a
 moderate effect of behavior; $F(2, 28) = 3.2$, Roy's Root = 0.23, $p < 0.1$. As before,
 17 *post-hoc* pairwise comparisons indicated that children were more likely to attribute
 intelligence to the *dance* behavior compared to *stand still* ($p < 0.05$), and *kick* was
 19 not different from the other two behaviors ($ps > 0.1$).

The same style of analysis was conducted for the three biology questions. The
 21 middle panel of Fig. 4 shows these percentages. The children showed very differ-
 ent levels of attribution for the three biology questions; $F(2, 28) = 6.06$, Roy's

^bStrictly speaking, a Manova is not ideal for this analysis, because the data are restricted to 1's and 0's (did the child indicate the dog for the given question?). The previous analysis used the summed scores across the three intelligence questions, which ranged from 0 to 3. However, the results are more interpretable for most readers, and the statistical patterns are consistent with more arcane analyses.

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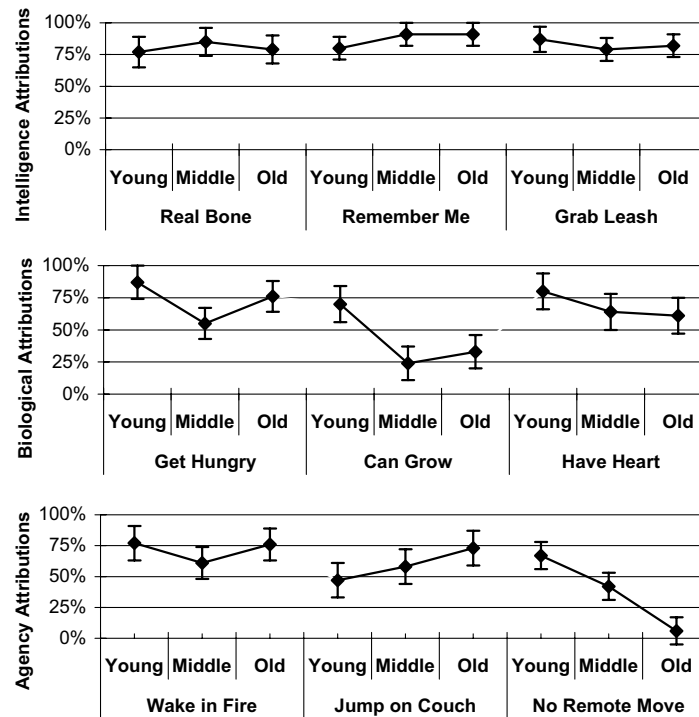


Fig. 4. Children's attributions broken down by question and age.

1 Root = 0.43, $p < 0.01$. Pairwise comparisons indicated that children were much less
 2 likely to accept that the robots could grow compared to having a heart or getting
 3 hungry ($ps < 0.01$). There were no other effects.

4 Finally, the analysis was repeated for the agency questions. For agency, there
 5 is the first evidence of a significant effect of age. There was a question by age
 6 interaction; $F(2, 29) = 5.7$, Roy's Root = 0.39, $p < 0.01$. The bottom panel of Fig. 4
 7 shows opposite effects of age for the jump-on-couch and move-without-remote-
 8 control questions. The young children frequently thought the robots could move
 9 without a remote control, whereas the old children rarely thought the robots could
 10 move without a remote control. Inversely, the young children were less likely to
 11 think the robots would jump on the couch, whereas the older children thought it
 12 might. There was also a main effect of behavior; $F(2, 28) = 4.4$, Roy's Root = 0.31,
 13 $p < 0.05$. Children were more likely to attribute agency to the dance behavior but
 14 not the stand still behavior, $p < 0.05$.

15 4.3. Discussion

16 We proposed three predictions that would indicate that children have a piecemeal
 17 understanding of animacy, at least when they need to apply it to the boundary

1 object of a robotic dog. The first hypothesis was that children would not confer ani-
2 mistic properties evenly. The results supported this hypothesis. Children attributed
3 intelligent behavior more than biology and agency. Moreover, within classes of ani-
4 macy, the children varied in their responses. For biological properties, the older
5 children believed the robots get hungry and have a heart, but they did not believe
6 they grow. For agency, almost no older children thought the robot could move with-
7 out a remote control, but over three-quarters thought the robot might jump on the
8 couch when left alone. Thus, if these children had a theory of animacy, it would
9 have to be highly idiosyncratic, because it did not appear to entail a set of necessary
10 features derived from an integrated belief system.

11 The second hypothesis was that children would show select changes in their attri-
12 butions of animacy with age. So, rather than replacing one theory with a new one,
13 they would simply change discrete beliefs, based on facts they may have acquired
14 during development. The results supported this hypothesis. The younger children
15 attributed animate properties relatively consistently across the different questions.
16 To view this as an indication of a theory, it would be necessary for the children to
17 reject attributions of animacy with equal consistency across categories. The older
18 children, who presumably would have a more mature theory, did not reject animacy
19 properties whole cloth. Instead, the older children accepted some biological attribu-
20 tions, but rejected the ability to grow. They also accepted some agency attributions,
21 but they rejected the ability to move without a remote. One explanation for the
22 spotty beliefs for the older children is that they had learned that growing things
23 need “soft” exteriors not plastic shells and that toys need remotes. Knowledge of
24 these select facts, however, did not prevent them from believing that the robots ate
25 food or that the robots could choose to be bad dogs and jump on the couch.

26 The third hypothesis, and most relevant to the practical design of robots, was
27 that the children would not tie specific animacy attributes to specific behaviors.
28 The children did attribute more animacy properties to the dancing robot than the
29 still robot. So, this means that a moving robot is more likely to elicit the belief
30 that it is animate. Similarly, the children were unlikely to attribute growth to any
31 of these robots, which may be a result of their hard shell. So, it appears that the
32 children do connect their beliefs of animacy to specific empirical features. However,
33 this connection is not theory-like, because the children did not specify classes of
34 attributes associated with indicative behaviors; the children did not attribute more
35 intelligence or agency to the kicking robot, which showed the most cleverness by
36 noticing and locating a ball. In fact, they attributed more intelligence to a dog that
37 was turned off than they attributed properties of biology or agency to a moving dog.

38 This study indicated that children bring an eclectic set of attributions to robots
39 and that these attributions are only mildly connected to the range of behavior
40 available to the robot. A limitation of the study, however, is that the children
41 only saw the robots briefly, and the robots did not show a large range of behaviors.
42 Moreover, the children did not get to interact with the robots. Contemporary enter-
43 tainment robots can produce behavior that is highly contingent on what children

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1 do with them. Interacting with robots with high contingency may alter the patterns
of attribution.

3 A second limitation of the study is that some of the children may have thought
they were supposed to treat the robots *as though they were alive*. For example, the
5 older children may have been playing along that the robots have a heart. But, when
it came to the remote control question, the older children decided that they were
7 being asked if they thought the robot was really alive. A useful second study would
examine whether children actually think the robot is alive and whether this affects
9 their attributions.

5. Study 2: Attributions through Physical Interaction

11 The second study attempted to address some of questions raised by the first study.
One question was whether an interactive experience with a more or less respon-
13 sive robot influences children's attributions. Therefore, in this study, half of the
children interacted with a robot that had highly contingent behavior, and half the
15 children interacted with a robot that was not responsive. (In this study, children
only interacted with one robot.)

17 A second question came from the interesting finding that older children thought
the robots could not grow, even though they could get hungry and have a heart.
19 Perhaps, this pattern of inconsistent biological attribution was simply the result
of the children believing that not all things grow. After all, their parents had not
21 grown taller. Alternatively, this failure to attribute growth may be just one instance
of a larger pattern of inconsistent biological attribution. To address this question,
23 each child answered six questions (shown in Table 2) that probed their biology and
sensory attributions towards their robot.

25 A third question was whether children really thought the robot was alive, or
whether they were just playing along that it was alive. There is a large body of
27 research on children's abilities to pretend,^{23,24} and therefore, it is important to
find out how their attributions differ when they believe the dog is alive or not.
29 To address this question, we asked the children if they thought the robot was alive.
This permits us to analyze how biological attributions differ when children believe
31 the robot is alive or not. It also allows us to see if a more interactive robot leads
children to believe the robot is alive.

Table 2. Questions for biology and intentions.

Questions: Do you think "Chai" ...? How can you tell?	
Biology	1. ... needs to have food? 2. ... pees and poops like we do? 3. ... breathe? 4. ... can see the toy? 5. ... can hear me? 6. (Experimenter hits the robot) Do you think it hurts "Chai" ?
Alive/Real	1. Do you think "Chai" is alive or not alive? How can you tell?

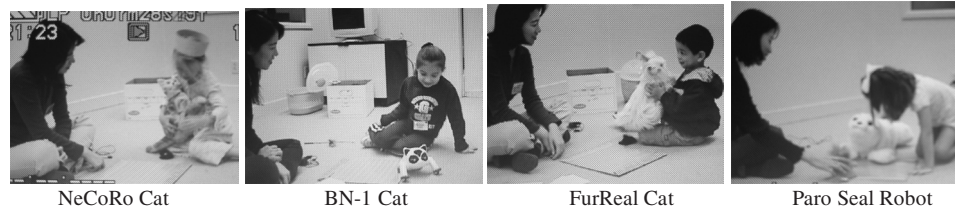


Fig. 5. Children in Experiment 2 interacted with robotic animals.

1 Our predictions for this experiment are similar to the previous one. Children will
 2 not make consistent attributions across biological properties. Older children will
 3 show piecemeal changes relative to younger ones; the older children will not change
 4 from accepting all biological attributions to rejecting all biological attributions.
 5 We also thought that the contingency level of the robot would make very little
 6 difference. The first study seemed to imply that the key feature for the children was
 7 whether the robot moved or not. In this study, all the robots moved. The difference
 8 between conditions was simply whether the robot moved in response to the child.
 9 Our assumption is that coherent movement is the key for children, and that their
 10 beliefs about animacy are not tied to the responsiveness of an organism.

11 We did not have strong predictions about the frequency children would say the
 12 robot is living. We also did not know what would happen to children's attributions
 13 when they thought the robot was alive or not. One possibility is that children do not
 14 have a good concept of alive to start with, so whether or not they think the robot is
 15 alive would be somewhat arbitrary and without influence. An alternative possibility is
 16 that all the children would say the robot is not living, in which case, our results would
 17 simply indicate the ways children are willing to pretend with entertainment robots.

5.1. Method

19 *Participants.* Sixty-one children from the same university day-care program partic-
 20 ipated. The children comprised three age groups: young ($n = 20$, $M = 42.8$ months,
 21 range 35–48 months), middle ($n = 21$, $M = 53$ months, range 49–56 months), and
 22 old ($n = 20$, $M = 60.3$ months, range = 57–66 months).

23 *Design.* Children from the three age levels interacted with either a high- or low-
 24 contingency robot. There were four robotic animals (shown in Fig. 5). Two were
 25 for the high-contingency condition, and children saw and interacted with only one
 26 of them (Omron's NeCoRo Robot cat^c or AIST's robotic seal Paro^d). There were
 27 also two robots used for the low-contingency condition (Bandai's BN-1 cat or Tiger
 Electronics' Furreal cat). The high contingency robots had a relatively realistic

^cThe communication robot NeCoRo cat was generously donated by Omron Corporation, Japan.

^dThe robotic seal Paro was generously loaned from the Advanced Industrial Science and Technol-
 ogy (AIST), Japan.

1 appearance and were capable of responding to different types of input (e.g. pushing
back lightly when held, responding to name). The low contingency robots were less
3 realistic in appearance (more like a toy) and had a smaller repertoire of contingent
responses. Unlike Study 1, there were no specific behaviors the robots performed;
5 however, the robots did generate sounds and move (e.g. meow, squeak, move body
parts), and in the high contingency condition their behaviors were in response to
7 the child. During the interaction, children answered six questions that mapped into
attributions of biology and sensation. Table 2 shows the listing of the questions.
9 Children that answered “yes,” received a score of 1 for that question, and received
a score of 0 for “no.” At the end of the session, children were asked “Do you think
11 Chai is alive or not alive?”

Procedure. Children participated separately in 10–15 minute videotaped sessions.
13 On entering the room, children were asked to wait quietly as the experimenter went
into the back. The experimenter returned with one of the robots, already turned on.
15 The children physically interacted with their robot through actions such as holding,
waving their hands in front of it, petting, and tugging. After children had a couple
17 of minutes to interact with the robot, they heard the biology questions one at a
time in the same order. For each question, the children indicated with a “yes” or
19 “no” if they thought the robot could do what the question proposed. Afterwards
they answered whether they thought Chai (the robot) was alive.

21 5.2. Results

Older children were less likely than the younger children to attribute biological
23 properties to the robots. Across the six biology questions, a percentage of positive
attributions was calculated for each child. This aggregate score was the dependent
25 measure in an age by contingency level univariate analysis. As reflected in Fig. 6,
there was a significant effect of age; $F(2, 55) = 4.17$, $MSE = 2.99$, $p < 0.05$. Older
27 children were less likely to attribute biological properties to the robots than young
children. So, unlike Study 1, where there was a descriptive affect of age on biology
29 attributions, the effect reached significance here. There was not a significant effect
of the robot’s contingency and no interaction of age and contingency; $ps > 0.1$.
31 However, Fig. 6 indicates that as children get older, they are less likely to attribute
biological properties to the less interactive robot. A subsequent study that used
33 a larger sample size or more interactive robots might bring this descriptive inter-
action to the level of significance. Regardless, the data strongly suggest that the
35 contingency of the robot has no effect on three-year-old children’s attributions of
biological properties.

37 A second question is whether the age of the children or the robot’s contin-
gency had an influence on whether children believed the dog was alive. Table 3
39 shows the percent of children at each age and contingency level who said their
dog was alive. To determine if the differences were significant, we used a logistic
41 regression of age by contingency on whether the child thought the robot was alive.

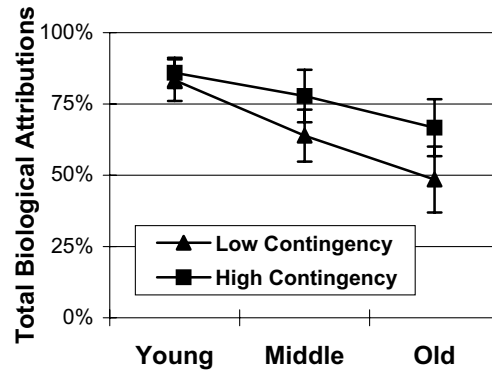


Fig. 6. Average percentage of biological attribution (out of six questions) by robot contingency and age.

Table 3. Percent of children that said the robot was alive.

Age	Low Contingency(%)	High Contingency(%)
Young	43	31
Middle	50	67
Old	45	56

1 There were no significant effects; $ps > 0.2$. Thus, the behavior of the dog did not
 2 have a stable affect on the children's beliefs about whether the robot was alive.
 3 Descriptively, Table 3 shows that the younger children were less likely to attribute
 4 aliveness to the highly contingent dog. One possible explanation is that the contin-
 5 gent dog was threatening, and therefore, they were less inclined to want to believe
 6 it was alive.

7 The next question is whether children's belief that a robot dog was alive influ-
 8 enced their biological attributions. We conducted a second univariate analysis on
 9 the percentages of biological attributions. The factors were the children's age and
 10 whether the child said the robot was alive or not. As before, there was a strong effect
 11 of age; $F(2, 49) = 7.41$, $MSE = 1.5$, $p < 0.01$, such that younger children made
 12 more biological attributions. This analysis also indicates that if children thought
 13 the robot was alive, they were much more likely to attribute biological properties;
 14 $F(1, 49) = 30.5$, $p < 0.001$. There was also a strong interaction between age and
 15 alive; $F(2, 49) = 7.64$, $p < 0.01$. Figure 7 shows the effect. Older children who
 16 thought the robot was alive were much more likely to attribute biological proper-
 17 ties compared to older children who did not think the robot was alive. In contrast,
 18 the young children attributed biological properties at the same rate, regardless of
 19 whether they said the robot was alive or not. Evidently, younger children do not
 20 associate "alive" with biological properties, and it seems probable that their cate-
 21 gory of "alive" is not well defined.¹⁵

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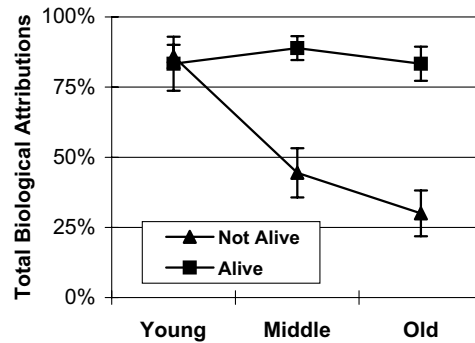


Fig. 7. Level of biological attribution by age and their belief that the robot was alive.

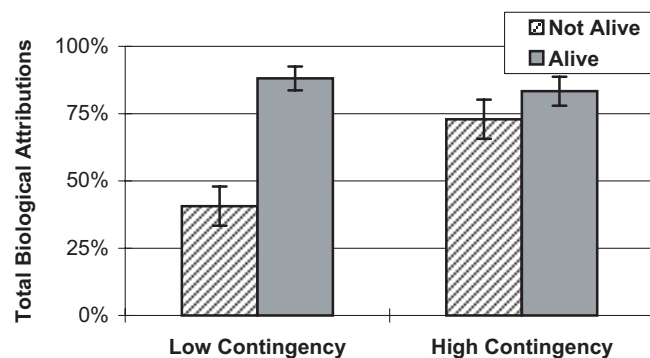


Fig. 8. Biological attributions broken out by contingency level and attribution of living.

1 There was also a modest interaction of contingency by alive; $F(1, 49) = 5.39$,
 2 $p < 0.05$. As shown in Fig. 8, children in the low contingency condition who attributed
 3 aliveness made the highest percentage of biology attributions, but children in the low
 4 contingency condition who did not attribute aliveness gave the lowest percentage of
 5 biology attributions. We do not have a strong single explanation of this effect.

6 The next set of analyses consider how children responded to each biology ques-
 7 tion and whether this varied by age and attribution of aliveness. Age, contingency
 8 level, and attribution of aliveness were crossed, and each of the six questions served
 9 as a separate dependent measure in a multivariate analysis.^e The purpose of this
 10 analysis is to determine whether children show the same patterns of attribution
 11 for the different biological properties. That is, do the younger children attribute
 12 biological properties uniformly compared to older children, and does this vary by
 13 contingency level or attribution of aliveness?

^eAs before, each child only receives a “1” or “0” for each question, so an analysis of variance is not strictly appropriate. However, results are comparable to more arcane analyses.

1 To simplify matters, we only report significant multivariate effects of question
 2 type, and use Fig. 9 to show the patterns for the questions. There was a significant
 3 effect of question type; $F(5, 45) = 4.66$, Roy's Root = 0.52, $p < 0.01$. Children
 4 did not equally accept all biological properties for the robots. There was also a
 5 significant effect of whether children thought the robot was alive on their pattern
 6 of responses; $F(5, 45) = 2.59$, Roy's Root = 0.29, $p < 0.05$. Finally, there was a
 7 marginal interaction between age and alive on how children varied across the six
 8 biology questions; $F(5, 46) = 2.9$, Roy's Root = 0.25, $p = 0.06$.

9 Figure 9 indicates the source of the effects. Young children make the most biolog-
 ical attributions across all questions and these attributions do not vary by whether

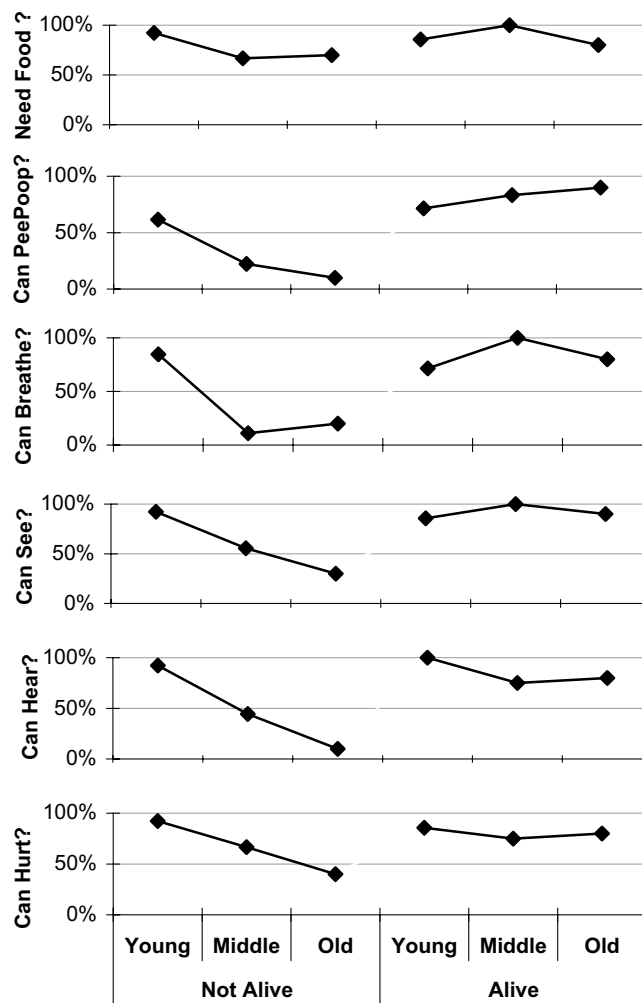


Fig. 9. Percentage of children who attributed a biological property broken about by age and belief in aliveness.

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1 they believe the robot is alive. Middle and older children, on the other hand, have
2 high attributions only when they say alive. However, there are exceptions. Children
3 attribute the need for food, regardless of their age and belief in aliveness. And,
4 whether the children believed the robot was alive or not had minimal influence on
5 the rate children at each age level thought the robot could feel pain (hurt).

5.3. *Discussion*

7 In the second study, children either interacted with a robot that responded directly
8 to their actions or just made various movements and sounds. The contingency of the
9 robot had relatively modest effects on the children's biological attributions or their
10 belief that the robot was alive. As the children increased in age they showed some
11 sensitivity to the contingency of the robot, such that they made somewhat fewer
12 biological attributions for the low-contingency robot. And, for the high-contingency
13 robot, 10–15% more of the four- and five-year-olds thought it was alive. Perhaps
14 these effects would reach significance in a subsequent study with modest changes
15 including a larger sample size and a longer period of exposure. A subsequent study
16 should also counter balance the type of robot by contingency level.

17 The results also indicated that children's belief in whether their robot was alive
18 had a large influence on their biological attributions. Though it made no difference
19 for the young children, it had a very large effect for the older children. If the older
20 children thought the robot was alive, their biological attributions were indistin-
21 guishable from the young children. They attributed all the biological properties at
22 high levels. One interpretation of this finding might be that pre-school children do
23 have a theory of being alive, because once they think a robot is alive, they confer to
24 it all the biological properties. However, we think this is a mistaken interpretation.
25 If the children had a strong sense of alive, then otherwise comparable children who
26 thought the robot was not alive should have rejected all the biological properties.
27 Instead, the older children who did not believe the robot was alive rejected some
28 biological properties, but not others. The children were quite willing to accept that
29 robots needed food, and nearly 50% of the five-year-olds thought the robot could
30 feel pain. These piecemeal changes in their biological attributions to a robot they
31 thought was not alive indicates these children neither have a theory of alive nor
32 a coherent concept of which biological properties come together (e.g. the children
33 said the robot needed food, but did not defecate).

34 An interesting question is why the older children, who thought the robot was
35 not alive, still maintained that the robot needed food and to some degree thought it
36 felt pain. One possibility involves the prevalence of food and pain in stories around
37 stuffed animals and dolls. The narrative for play often involves activities such as
38 feeding the baby and dining, as well as treating and healing.²⁵ Sarbin²⁶ proposes
39 that the degree of involvement with a narrative corresponds to the reality of that
40 narrative (cf. Ref. 27). So, although the children may believe the robot is not alive,
41 the strength of their familiar narrative has a stronger sense of reality. This strong

1 sense of reality drives that particular piece of their network of beliefs regardless of
2 their other beliefs. If children do have a coherent theory of animate properties, it is
3 not evident in these studies.

6. Conclusion

5 Two studies explored three- to five-year-old children's "animistic intuitions." The
6 studies examined whether children attributed intelligence, biology, and agency to
7 entertainment robots. These three classes of animate behaviors are typically asso-
8 ciated with real, living beings. A practical question was whether the realism of the
9 robots influenced the children's attributions. In one experiment, children watched
10 the behaviors of robots with no direct interaction, while in the second experiment,
11 children had direct physical interaction with the robots. The studies indicated that
12 there was a mild influence of the realistic behavior of the robots. A moving robot
13 received more animate attributions than one that did not move, and for older chil-
14 dren, the interactive responsiveness of the robot had a modest, but non-significant
15 effect on their attributions. In general, the results suggest that improving the realism
16 of the robots does not have a tremendous effect on children's conceptual beliefs.

17 This result, however, does not mean that the realism of a robot does not have
18 other effects. Recall that our primary argument is that children do not have a very
19 well-developed concept of what it means to be alive or animate. By this argument,
20 the place to look for the effects of robot realism is not going to be in children's ideas
21 or beliefs. It may be better to look at other variables, for example, are the children
22 more attracted to realistic robots or do children engage in longer interactions with
23 realistic robots?

24 We suspect, however, that realism *per se* is probably less important for pre-school
25 children. Rather, it is more important to include features that enable the children
26 to bring to bear familiar schemas so they can sustain a productive interaction²⁸
27 with the robot. Unlike a doll or stuffed animal, the robot responds to children.
28 This means the child's ability to pretend is constrained by what the dog will do in
29 response. Until such time that robots have the intelligence to flexibly respond to
30 children's interactive bids, children will have to follow a well-known script (e.g. a
31 tea-party script) so the children can be sure to stay within the repertoire available
32 to the dog. If children cannot bring to bear a strong schema, the children will try
33 a number of interactive bids to see what emerges, but the robot will not be able to
34 respond flexibly and the children will get frustrated.

35 The studies were also intended to develop a portrayal of child development
36 around the notions of "animate" and "alive." The studies differ from other devel-
37 opmental studies because they looked at how children learned to *let go* of animacy
38 attributions. This has the merit of seeing how children handle evidence or beliefs
39 that partially conflict with their prior beliefs. If children have coherent knowledge,
40 then "falsifying" evidence or beliefs should make them let go of other purportedly
41 related beliefs about animacy. This was not the case in the current studies. Children
merrily attributed some properties and not others.

1 The studies provided a clear portrayal of how children of different ages treat
entertainment robots. The youngest children broadly attributed animate properties
3 to all the robots. This attribution is unlikely to be the result of any coherent theory.
For example, whether or not they said the robot was alive, they offered the same
5 high level of biological attribution. Rather, the results seem to be due to a general
tendency to over-extend all the facts that they know about dogs. Notably, the
7 exceptions to their over-extension of what they know about dogs involved questions
that had a moral component. For example, the youngest children were the least
9 likely of the age groups to say the robot could jump on the couch when nobody was
there. It seems likely that they were not reasoning about “could” for this question,
11 but rather, they were reasoning about “should.” A good dog would not jump on the
couch. Perhaps a good design for an entertainment robot for young children would
13 be a “naughty” dog that learns to be good. This is a very familiar schema children
could bring to bear.

15 Starting at four years and increasing into five years, children begin to develop
a meaningful distinction between alive and not alive. If children believe a robot is
17 alive, their attributions still look very much like young children. But, they differ
from young children, because if they think a robot is not living, they are much less
19 likely to attribute biological properties. Their notion of alive is becoming connected
to the attributes of animacy. At the same time, they do not have a fully developed
21 concept of animate or alive. The relevant evidence comes from their willingness to
attribute some qualities of animate things but not others. For example, the children
23 believed that the robot needs food but does not defecate. Rather than having a
strong model of what it means to be animate, the children appeared to be slowly
25 shifting which facts should apply to the strange category of entertainment robot.
Nearly all of the five-year-olds, for example, believed that the motionless robot
27 needed a remote control to get “animated,” but over 50% were still willing to say
that it had a heart. The fact that the children were making piecemeal adjustments
29 to their understanding does not mean the children were not searching for coherence.
Perhaps children are theory builders,²⁹ and the concepts of alive and animate are
31 simply difficult.

Boundary objects, like the monsters Dracula and Frankenstein, have long
33 revealed the weaknesses in people’s belief systems. Though people know they are
only fictions and it is only a movie, the combination of categories such as alive and
35 dead can trigger responses that defy people’s beliefs. Perhaps children are not so
different from adults. Regardless of the quality of one’s belief system, the place to
37 look for the affects of entertainment robots may not be in the world of concepts
and words. It may be in affective responses that can operate regardless of beliefs.

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