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Robotic Pets in Human Lives: Implications for the Human–Animal Bond and for Human Relationships with Personified Technologies

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Robotic "pets" are being marketed as social companions and are used in the emerging field of robot-assisted activities, including robot-assisted therapy (RAA). However, the limits to and potential of robotic analogues of living animals as social and therapeutic partners remain unclear. Do children and adults view robotic pets as "animal-like," "machine-like," or some combination of both? How do social behaviors differ toward a robotic versus living dog? To address these issues, we synthesized data from three studies of the robotic dog AIBO: (1) a content analysis of 6,438 Internet postings by 182 adult AIBO owners; (2) observations

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and interviews with 80 preschoolers during play periods with AIBO and with a stuffed dog; and (3) observations and interviews with 72 children, aged 7–15 years, who played with AIBO and a living dog. Overall, the studies revealed that "hybrid" cognitions and behaviors about AIBO emerged: the robotic dog was treated as a technological artifact that also embodied attributes of living animals, such as having mental states, being a social other, and having moral standing (although this latter finding remained difficult to interpret). Implications for use of robotic pets as companions and in interventions or therapy are explored.

The benefits of animal companionship for human well-being continue to be the subject of considerable debate. Evidence for the beneficial effects of pet ownership on human health and well-being remains mixed (McNicolas et al., 2005). On the other hand, a recent meta-analysis of quantitative assessments of animal-assisted therapy (AAT) outcomes found moderate effect sizes in improving autism-spectrum disorders, medical conditions, behavioral problems, and emotional well-being (Nimer & Lundahl, 2007). At the same time, barriers to animal-assisted interventions (which broadly include AAT and nontherapeutic animal-assisted activities, such as classroom pets) include animal welfare issues, cultural diversity in attitudes toward animals, concerns about zoonotic diseases and human allergies, and liability issues, among others (Wilson & Barker, 2003).

Technological advances in interactive computing and virtual reality are yielding increasingly sophisticated emulations of the natural world. Of special interest are robotic pets, which embody interactive and adaptive computing technology in forms that mimic biological entities such as dogs and cats. Sony's robotic dog AIBO, marketed as a social companion, has a dog-like metallic form, moveable body parts, and sensors that can detect distance, acceleration, vibration, sound, and pressure. As one of its compelling activities, AIBO can locate a pink ball through its image sensor, and walk toward the pink ball, kick it, and head butt it. As people interact with different AIBOs, each robot learns slightly different sets of behaviors.

There is increasing interest in examining AIBO's potential as a social companion and adjunct to therapy, especially for vulnerable populations. For example, elderly with severe dementia increased their activity and social behavior with AIBO as compared to a stuffed animal (Tamura et al., 2004), while children showed positive responses to AIBO during shared reading (Decuir et al., 2004). While advocates argue for the advantages of robotic social companions, skeptics (Sparrow, 2002) caution that robotic substitutes may deprive isolated or vulnerable individuals of the benefits of a living animal, such as a therapy dog or pet.

Over the next decade, it is likely that robotic pets will become not only more computationally sophisticated and capable of action, but also more available for use (Aylett, 2002; Turkle, in press; Yokoyama, Ribi, & Turner, 2004). Thus, important social issues emerge. For example, can robotic pets, compared to biological pets, provide children and adults with similar outcomes related to social companionship or improved quality of life? Can such robots become our social companions or even friends? And if they can, might we also accord such robots some degree of moral standing (e.g., such that we care for them as an "other," respect them, and perhaps accord them some measure of rights)?

Answers to such questions have both theoretical and practical implications. With respect to theory, there is a good deal of evidence under the rubric of the "biophilia hypothesis" (Kahn, 1999; Kellert, 1997; Kellert & Wilson, 1993; Wilson, 1984) that humans have a predisposition to affiliate with life. Yet it has remained an open question—one that can be explored through people's interactions with a robotic dog—the extent to which such affiliations extend to artifacts that mimic life forms and processes. Moreover, such explorations can help answer foundational questions about what specific features of life forms focus human attention, stimulate interaction and activity, provide companionship, provide cognitive enrichment, and establish conditions to accord an entity moral regard. With respect to practical applications, research on these questions could help shape the design of future robots, and establish parameters for understanding beneficial contexts of use. For example, it would be important to understand whether, and if so how, robotic pets could be used effectively to substitute for or at least augment AAT and visitation programs. Also, if robotic pets become more common as substitutes or supplements to living companion animals, such as dogs and cats, what implications might that have for the human–companion animal bond and for issues of animal welfare?

As technology mimics the natural world more and more expertly, a number of social issues arise: (1) What standards and protocols for robot-assisted activities, including robot-assisted therapy (RAA) should be developed? (2) Should public policies encourage the ownership or use of robotic pets or "assistants" particularly for special populations, such as the elderly, persons with disabilities, or immunosuppressed individuals? (3) Will mediated experiences with animals and nature (robotic pets, virtual pets, videogames) come at the expense of direct human engagement with the living world, as Louv (2005) and others (Heerwagen & Orians, 2002) warn, thereby threatening children's optimal development and their environmental and animal welfare concerns?

There is a paucity of research to address these theoretical, practical, and social questions. Before the social implications of robotic analogues of human–animal interaction can be addressed, we must better understand how individuals view and behave toward a robotic pet. Pepe et al. (2008) showed that undergraduates attributed more positive characteristics (cooperative, responsive, affectionate, obedient) and used a higher voice register when they thought they were guiding a live dog rather than AIBO through a maze. (They did not directly interact with either dog.) In direct observation of children and adults with AIBO and a live dog, Kerepesi et al. (2006) found fewer structured behavioral interactions with AIBO. Yokoyama et al. (2004) noted that most of the kindergarten children who interacted with AIBO and with a live dog over 11 weekly sessions preferred the live dog. Although these data suggest that AIBO is a poor substitute for a living dog, Pepe et al. (2008), Kerepesi et al. (2006), and Yokoyama et al. (2004) all found that children and adults engaged AIBO as a social partner to some extent.

To better understand how individuals view and behave toward a robotic dog such as AIBO, we draw on three studies. These studies comprise (1) observations of and interviews with 80 preschoolers, aged 3–5 years, during a 40-minute play period with AIBO and a stuffed dog (Kahn, Friedman, Perez-Granados, & Freier, 2006)—which we refer to as the Preschool Study; (2) observations of and interviews with 72 school-age children, aged 7–15 years, who played with AIBO and a unfamiliar, friendly living dog (Melson et al., 2009)—which we refer to as the Developmental Study; and (3) a content analysis of 6,438 Internet discussion forum postings by 182 AIBO owners, all presumably adults (Friedman, Kahn, & Hagman, 2003)—which we refer to as the Discussion Forum Study. While each of these studies has been previously published, our goal in this paper is to draw on these data (along with new, previously unpublished analyses) to inform a conceptual framework to better understand human–animal interaction by comparing and contrasting it to human–robotic animal interaction.

Based on the above studies, we address five central issues that shed light on how robotic pets and living pets may be similar and different: (1) how individuals of different ages understand AIBO in terms of its biology, mental life, and sociality; (2) how individuals of different ages understand AIBO in terms of its moral standing; (3) how such understandings about AIBO differ from those toward a living dog; (4) how individuals behave with both a robotic dog and living dog; and (5) whether individual variables—age, gender, pet ownership history, and technology involvement—predict cognitions about, emotions toward, or behavior toward robotic pets and living dogs. In addressing these issues, we consider the ways in which human–robotic animal interaction might shed light on human–living animal interaction and vice versa. We close by considering the social issues raised by human engagement with living and technological analogues of animals.

How Individuals Conceptualize a Robotic Pet

The human mind seeks to categorize many aspects of the world. We focus in this section on three overarching categories. First, humans categorize entities as alive/dead or never alive, or specifically, as belonging to the biological or nonbiological domain. Some nonbiological entities, such as televisions, are seen as man-made artifacts, and others, such as rocks, are viewed as the product of natural processes. Second, some entities are categorized as having a mental life, with intentions, desires, and thoughts. Third, some entities are categorized as social. We may enjoy their company, feel less lonely in their presence, and be their friends.

These three domains—biological, mental, and social—have informed our study of robotic pets and their implications for human–companion animal interactions. These domains provide fundamental cognitive structures that organize thoughts and influence (but do not determine) actions and feelings. As cognitive structures, domain assignment implies attributes and processes. For example, if an object such as a robotic pet is seen as having a mental life, its behavior is likely to be interpreted as internally controlled by internal cognitive or emotional states (e.g., it moved because it "wanted" or "intended" to) as opposed to externally regulated by human control via computer chips, batteries, and sensors. Thus, domain or category assignment allows us to infer additional information, often unseen and untested, about an object or being.

These domains are overlapping but not redundant. When we attribute autonomous mental processes to an object, we tend also to view the object as having biological properties, although advances in artificial intelligence are challenging this association. Similarly, when we engage another as an interactive partner, or social companion, we often attribute to them mental and biological characteristics. However, many pets function for children and adults as social companions while viewed as having limited mental agency and humans appear to derive a sense of social presence and support from a range of nonbiological objects (e.g., a child's imaginary friend). Thus, we treat these domains as distinct but interrelated.

Research on *naïve biology*, the developmental processes by which children assign biological categories, attributes and processes, suggests that by age 4–5 years, children can accurately label unfamiliar animals, plants, and machines and select appropriate internal parts for animals (e.g., bones) and machines (e.g., batteries; Gottfried & Gelman, 2005). By age 6, children understand that animals but not machines move because of an internal "vital energy" or life force, although it will be some years before they can explain the underlying biological processes (Carey, 1991).

While children distinguish animals and machines from an early age, machines that emulate biological entities and contain sophisticated interactive capabilities may pose challenges. AIBO has artifactual features (gray metal, flashing lights, and chiming sounds) but it also mimics the shape, motions, and reactions of living dogs. Thus, it is unclear whether children (or adults) would assign AIBO to the biological or technological domain. Barlett, Estivill-Castro, and Seymon (2004) found that children saw AIBO as a robotic pet rather than a canine machine, suggesting that children see elements of both animal and machine in this unfamiliar technology. The interactive capacities of AIBO might make it seem as though the robotic pet is behaving intentionally, leading to the inference of mental characteristics. The shape and behaviors of AIBO are meant to evoke a living dog. To the extent that the design successfully does this, it is likely to “pull” on the repertoire of behaviors and emotions that are part of the Human–Companion Animal Bond (HCAB). Because AIBO was designed as a “social robot” that evokes an association with the powerful companionship benefits of living dogs, we expected that it would be viewed as a social companion. However, the sense in which it functions in this domain is unclear. After all, children and even some adults form attachments to objects—stuffed animals, dolls, special “blankies,” and for some adults, sports cars, treating them in some ways as if they were social intimates. Is a robotic pet more like a stuffed animal or like a living dog?

In the Preschool Study and the Developmental Study, we constructed an interview protocol that tapped the biological, mental, and social domains. Each question elicited a yes/no answer, reflecting the child’s affirmation (yes) or negation (no) of the domain characteristic being tapped. For example, to assess children’s judgments of mental life, one question was “Can AIBO feel happy?” In addition, following Piaget’s method for probing children’s cognitions (Piaget, 1965), we used prompts—“Why?” “How do you know?” “Tell me more about that”—after each yes/no response to tap the respondent’s underlying reasoning, and then we coded the responses for justifications based on domain membership, attributes, and processes.

Table 1 shows responses to each of the domains, as indexed by a subset of questions tapping each domain. Participants in both the Preschool and Developmental studies answered each of these questions, although the wording varied slightly to ensure that questions were age appropriate. Preschoolers more strongly endorsed AIBO’s biological characteristics than did older children. Closer inspection of responses to all the questions revealed that the older children were most likely to affirm those biological characteristics that have become common analogies for technological artifacts, especially computers. Specifically, while 66% of the 7–15-year-olds agreed that AIBO “could die” and 31% agreed AIBO “could get sick,” their justifications sometimes provided evidence that they thought of such ideas metaphorically: for example, in terms of batteries dying and computer viruses. However, those preschoolers who justified their affirmations of biology did so with more literal ascriptions of biological processes to AIBO.

In addition to questions about specific biological properties and processes, both preschoolers and older children were asked a global question—“Is AIBO alive?”—to tap the “alive/not alive” dimension, which research on naïve biology has shown to be distinct from but related to attributions of specific biological attributes (Inagaki & Hatano, 2002). Among preschoolers, 38% agreed that AIBO was alive. Among older children, 23% of 7–9-year-olds, 33% of 10–12-year-olds, but only 5% of 13–15-year-olds agreed. Examination of justifications for “alive/not alive” responses revealed nuanced or qualified responses. For example, one child spoke of AIBO being alive in its own robot way: “He [AIBO] is alive,

Table 1. Percentage of Children Who Affirm Domain Characteristics for AIBO, Live Dog, and Stuffed Dog

Domain	Preschool Study: AIBO	Preschool Study: Stuffed Dog	Developmental Study: AIBO	Developmental Study: Live Dog
Biological				
Stomach	72	78	26	99
"Go to bathroom"	31	35	9	100
Babies	49	45	6	98
Mental				
Happy	74	75	75	100
See toy	68	65	79	98
Hear you	45	48	60	97
Social				
Do you like	85	85	81	100
Does dog like you	80	84	68	96
Can dog be your friend	76	82	84	99
Can you be dog's friend	76	84	88	99
If sad, be with dog	64	68	76	97
Moral				
Not OK to hit	69	73	78	85
Not OK to punish	61	60	51	26
Not OK to throw away	86	87	84	100

Note. In the study of preschoolers, half the children answered questions about AIBO and half answered questions about a stuffed dog. In the study of 7 – 15-year-olds, each child answered all questions twice. The questions above are a subset of the total number of questions asked. This subset includes only those questions asked in all three studies. Wording of questions varied slightly across studies.

for a robot." Here again, then, it is not straightforward to interpret children's judgments about robotic pets, for there are indications that some children want to make some claims about the biological properties of AIBO.

Such indications were both more prevalent and clearer to interpret in the Discussion Forum Study where 49% of the participants posted at least once an idea that spoke of AIBO as having life-like essences. For example, one AIBO owner wrote:

> The other day I proved to myself that I do indeed treat him as if he were alive, because I was getting changed to go out, and tba [AIBO] was in the room, but before I got changed I stuck him in a corner so he didn't see me! Now I'm not some socially introvert guy-in-a-shell, but it just felt funny having him there!

This posting highlights the possibility that when people interact with AIBO "as if" it were alive, the nature of the interaction can go beyond mere metaphor, imagination, or pretence, evoking some feelings and judgments about AIBO's aliveness even while recognizing it as a technology.

Across the three studies, most participants viewed AIBO as having a mental life that included thoughts and feelings. One adult AIBO owner posted this entry: “My dog [AIBO] would get angry when my boyfriend would talk to him.” An 11-year-old boy in the Developmental Study replied when asked “Why is AIBO moving his ears like that?”—“I think he’s happy. If he likes company, he’s happy.” [As these examples show, responses about AIBO could include elements of multiple dimensions, such as attributing mental processes (being happy, liking) and social characteristics (liking company).]

Similarly, the majority of participants across all three studies endorsed AIBO as a social companion. For example, as shown in Table 1, the majority of preschool children and older children said that AIBO could be their friend, that they could be a friend to AIBO, and that if they were sad they would like to be in the company of AIBO. In turn, in the Discussion Forum Study, 59% of the participants posted at least one comment that spoke of AIBO in terms of its social rapport. Here is an example:

> Oh yeah I love Spaz [the name for this member’s AIBO], I tell him that all the time. . .When I first bought him I was fascinated by the technology. Since then I feel I care about him as a pal, not as a cool piece of technology. I do view him as a companion, among other things he always makes me feel better when things aren’t so great. I dunno about how strong my emotional attachment to him is. . .I find it’s strong enough that I consider him to be part of my family, that he’s not just a “toy,” he’s more of a person to me.

In other words, even while the person recognizes that AIBO is a technology (“When I first bought him I was fascinated by the technology”), the person still affirms AIBO as a companion (“I do view him as a companion”), as part of his family (“I consider him to be part of my family), and as a friend (“I care about him as a pal”). These social responses parallel those commonly ascribed to living pets.

In sum, both children and adult owners recognize AIBO as a product of technology but nonetheless give the robotic dog many of the attributes of a living dog. This appears to support the view that a robotic dog, if sufficiently interactive, can fulfill some of the social companion functions of living dogs.

How Individuals Understand a Robotic Pet’s Moral Standing

The place of companion animals (and animals in general) within the moral domain is complex and poorly understood. Most pet-owning adults and children identify their pets as family members (American Pet Products Manufacturers Association, 2005), but abandonment of pets and their relinquishment to shelters are widespread. An estimated two million dogs are euthanized annually, accounting for one third of all canine deaths (Patronek et al., 1996). Human attitudes toward and treatment of wild, domestic, and companion animals are complex; animal welfare and humane education concerns wrestle with issues of how to treat animals who may be beloved companions, competitors for resources, food products, or medical research subjects. Because studies of moral reasoning have largely been restricted to issues of human–human relationships, little is known about how children and adults weigh the moral claims (or lack thereof) of animals. Only recently have moral-developmental investigations expanded to consider the human relationship with animals and the larger natural world (Kahn, 1999, 2006; Kellert, 1997; Myers, 1998). These studies suggest that both children and adults consider living animals to be part of the "moral universe," making some moral claims on human behavior. However, these claims are complex and as yet poorly understood.

If children and adults are ready to treat AIBO as if it were a living dog, at least to some extent, would they also accord it moral standing? Specifically, would they consider AIBO as having certain moral rights, such as the right to be free from harm? If so, would such moral rights be comparable to those accorded a living dog? As shown in Table 1, children in the Preschool and the Developmental studies were asked questions about AIBO's moral standing. (Table 1 displays only those moral standing questions asked in both studies, for ease of comparison. Additional questions were asked in each study to more fully explore children's ideas about the moral standing of AIBO.) Each question asked the child whether "it was OK" or "not OK" to treat AIBO in the following ways: to hit AIBO, to punish AIBO for wrongdoing, and to throw AIBO away "if you decided you didn't want AIBO any more." A "not OK" answer was judged to affirm moral standing, while an "OK" answer was judged to deny moral standing. Following each answer (affirmation or denial), the child was asked "Why?" and the explanations were coded for reference to the moral claims of the target dog.

In the AIBO Preschool Study, the majority of children said that it is not okay to hit AIBO, punish, or throw AIBO away. Moreover, 78% of the children backed up their evaluations with moral justifications, mostly focused on AIBO's physical welfare (e.g., "because he will be hurt") or psychological welfare (e.g., "because he'll cry . . . till when you finally come back"). In additional questions asked only in the Preschool Study (not shown in Table 1), all of the children said that the interviewer should do something to help AIBO if AIBO gets hurt (100%) or if AIBO's tail comes off (91%).

These results, however, are not easy to interpret. Preschool children provided similar evaluations when asked identical questions for the stuffed dog. Despite the similarity in evaluations, there may be qualitative differences in judgments about AIBO. Specifically, the preschoolers might have evaluated the stuffed dog in the context of their pretend play with the toy, while they may have actually held stronger commitments about the reality of their judgments about AIBO.

In the Developmental Study, among the 7–15-year-olds, there was strong condemnation ("not OK") of hitting or throwing away AIBO, but nearly half thought it was "OK" to punish AIBO. Ninety-two percent justified at least one of their yes/no answers (usually to a moral standing question) by explaining that AIBO deserved respect and care and should not be harmed. On average, the older children used moral standing reasoning about AIBO four times during their interviews.

By contrast, in the Discussion Forum Study, postings by (presumably) adults wrote of AIBO as having life-like essences (49%), mental states (60%), and social rapport (59%), but seldom as having moral standing (12%)—that AIBO deserves respect, has rights, or can be held morally accountable for action. Apparently these owners of the robotic dog treat AIBO "as if" it were a social companion, a biological being with thoughts and feelings, but feel it makes very few, if any, moral claims upon them. This finding should be viewed with caution, as postings were not responses to direct questions about AIBO's moral standing.

There are three reasons for why we believe it is particularly difficult—and an avenue for future research—to investigate people's moral engagement with personified robots. One reason we just touched on: that it is necessary to disentangle judgments of pretence from those of reality. With other biological beings, distinguishing between the two seems relatively straightforward. For example, if we see a person kick a dog and the dog yelps and runs away, most of us will assume that the dog, too, has experienced pain, and we will act as if the dog has experienced pain. Presumably, we are not "pretending" in our judgments and action, even while we do not know for sure if our judgments are true, or how exactly a dog's pain compares to a person's pain. But when the entity is a robot that mimics aspects of the biological animal, it is challenging to understand perceptions of the robot as "not really a real dog" but at the same time, not merely "a pretend dog."

A second reason that makes it difficult to investigate people's moral relationship with robots is that people can object to harm occurring to robotic forms out of concern for the destruction of a material artifact. As a case in point, Bartneck, Verbunt, Mubin, and Mahmud (2007) investigated whether adults considered a robot's exhibition of intelligent behavior as evidence that the robot was alive. Bartneck and colleagues assessed whether participants in their study would (under the guise of a plausible reason) destroy ("kill") their robot. Measurements included the number of times participants hit the "smart" robot versus "stupid" robot with a hammer, and the number of pieces into which each respective robot was smashed. Results showed that people hit the "stupid" robot three times more often compared to the "smart" robot. Yet one problem with this measurement is that the smart robot could be assumed to have been more expensive, and that what people were objecting to was really destroying expensive property, not the killing of a more intelligent life.

A third reason that makes it difficult to investigate people's moral relationship with robots is that people may object to harming robots because of a human-oriented teleological commitment against enacting violence in the world. In other words, it is plausible that people might object to striking a rock (or a robot) not because of any beliefs about the biology, mental life, sociality, or moral standing of the rock (or the robot), but because of a viewpoint on the proper moral teleos of human beings. This perspective has roots in Aristotle (1962) in *Nichomachean Ethics* and has been carried forward in more contemporary philosophical work in virtue ethics (Foot, 1978; MacIntyre, 1984). It is a moral view, but focused entirely on humans, not the entity.

Thus, our studies reveal that as personified robotic technology emulates living beings, questions about the moral standing of such technology artifacts arise. However, it is far from clear—to those who interact with these robots and to researchers—what that moral standing is. As the technology proliferates, perhaps a "techno-ethics" will develop alongside the bioethics that we currently debate in response to medical technology advances. We also need a lively debate about the broader impact of such a techno-ethics on our relations with living beings. Would our moral stance toward a robotic pet generalize to or influence that toward the living pet, or vice versa? Would our treatment of robots in some way affect how we treat diversity in other human or nonhuman living beings?

How Children Understand AIBO Versus a Living Dog

Although children in the Preschool Study did not interact with a living dog, these children were just as likely to affirm the stuffed dog's biology, mentality, social companionship, and moral standing as AIBO. Thus, at least for children aged 3–5 years, both robotic and stuffed analogues of living dogs become invested with many of the characteristics of living dogs themselves.

The Developmental Study of 7–15-year-olds directly compared children's ideas about a living and a robotic dog. In this study, children interacted with AIBO and with one of two unfamiliar, but friendly Australian Shepherds (mother or daughter). After each play period, they answered the same set of questions, once about AIBO and again about the living dog. (Order of play periods was counter-balanced.) When we compared both yes/no responses and follow-up justifications for each of those responses, we found strong type-of-"dog" effects across all four domains (see Table 1). Children were much more likely to affirm that the live dog (as compared to the robotic dog) was a biological, mental, social, and moral being. Affirmations about the living dog approached ceiling, ranging from 83% moral standing to 100% biological entity.

In addition, when children elaborated on their responses about the living dog, as compared to AIBO, the children were more likely to use justifications that the living dog was biological and mental, and warranted moral standing. When the same questions were asked about the live dog with which the children had briefly interacted, opposition to hitting or throwing away was even stronger (as compared to views about AIBO), but nearly three-quarters of the children thought it was "OK" to punish the living dog. Follow-up questions to tap the child's underlying reasoning revealed that children who endorsed punishment were drawing on their experiences of dog socialization, including punishment. They saw appropriate punishment (not endangering the welfare of the animal) as part of the necessary training of their own dog and by extension other dogs. Interestingly, some children generalized this to AIBO as well, as a "dog" who might require punishment to be properly trained.

However, the near uniformity among children in affirming a living dog's biology, mental life, sociability, and moral standing should not obscure the fact that the majority of children endorsed these characteristics for the robot dog as well. In fact, justifications based on social companionship were just as likely for the robotic dog as the living dog.

The human–companion animal literature finds that children overwhelmingly consider their pets to be friends and family members and accord their pets, and certainly their dogs, status as biological creatures with minds, emotions, and moral claims. Interestingly, these views appear to generalize to an unfamiliar friendly dog. Yet, in comparison to the living dog, children viewed the robotic dog as a much more restricted interactive partner. Nonetheless, the children in this study did see AIBO as a social companion, albeit a more limited one. This finding suggests that, for most children, a robotic pet (with the interactive capabilities of AIBO) might be well suited for situations where living animals are impractical or unwanted, while stuffed animals may be well suited as substitute companions for young children. Over time, and with greater sophistication and capabilities on the side of the robotic technology, it is possible that children will develop deeper attachments to robotic dogs and the distinctions between their responses about living and robotic dogs may narrow. From the child's point of view, robotic dogs may even have some benefits as compared with living ones. In focus group interviews we conducted with fourth-grade classrooms prior to the Developmental Study, some children expressed a hypothetical preference for owning a robotic versus living dog. "The robotic dog would never die, and so I would never be sad," said one girl. "We would save money on dog food and doctor visits," said a boy (who was apparently unaware of the then $2,000 price-tag for AIBO). "I could take AIBO to school and with me everywhere," said a third.

How Children Behave with a Robotic Dog

Observations of behavior with a robotic dog provide a different, complementary window into people's interactions with this emerging technology. In the Preschool Study, each of the 80 children participated in a 45-minute session with an adult interviewer, part of the period with AIBO and part with a stuffed dog. In the study of older children, each child spent 5 minutes interacting alone with AIBO and 5 minutes interacting alone with a live dog, with a 35-minute structured interview following each play period, during which the target dog remained present.

These play periods as well as the full 45-minute sessions for preschoolers were videotaped and coded for selected behaviors toward the target dogs. Specifically, we measured instances of treating the target dog as an artifact or machine (for example, poking, shaking) as well as instances of affection (e.g., hugging, petting, kissing, stroking) and attempts at reciprocal interaction (e.g. offering ball, talking to, motioning to). In addition, because children were interacting with unfamiliar objects, we coded any instances of apprehension.

For the preschoolers, when their behaviors toward AIBO were compared with those toward a stuffed dog, there was more exploration of AIBO as an artifact, more apprehension, and more attempts to engage it in reciprocal interaction. Preschoolers expressed equal amounts of affection toward AIBO as toward a stuffed dog.

Not surprisingly, as compared to a living dog, the 7–15-year-old children were more likely to explore AIBO as an artifact, and less likely to behave affectionately toward or socially engage AIBO. On average, 7–15-year-olds gave an unfamiliar but friendly live dog nearly five times as much affection as they gave to AIBO. In fact, many children spent the entire play period and subsequent interview time petting the live dog, with only one 7–15-year-old failing to pet the live dog during the session. Finally, Table 2 shows that behavioral attempts to engage, through motioning or offering a ball, or verbal attempts, such as commands ("Come!") or questions ("Do you want to play?"), were significantly more frequent toward AIBO than toward a stuffed dog (for preschoolers) or toward a living dog (for 7–15-year-olds). Thus, the robotic dog seems particularly effective in eliciting nonverbal and verbal interactive bids over the short play period available. In general, AIBO, though unfamiliar to all children, did not evoke apprehension, which occurred with low frequency in both studies. However, for a few preschoolers, its movements appeared to startle.

Table 2. Mean Frequency of Behaviors toward AIBO, Stuffed Dog and Live Dog

Behavior	Preschool Study: AIBO	Preschool Study: Stuffed Dog	Developmental Study: AIBO	Developmental Study: Live Dog
Exploration as artifact	2.76	1.88**	3.57	1.11***
Affection (pet, scratch, kiss, hug)	3.67	3.87	3.83	15.13***
Attempts at reciprocity (motioning, commanding, questioning, offering ball)	8.54	2.25***	17.60	12.58**
Apprehension	1.79	0.01***	0.36	0.62**

Note. Significant comparisons are within study. $^{**}p<.01$; $^{***}p<.001$

These results suggest that properly used AIBO or other robotic pets of similar technological sophistication may be helpful to elicit or maintain children's social interactions. While social robots (but not of the robotic pet type) have been considered in therapeutic interventions with children with autism-spectrum disorders (Dautenhahn, 2003), their effectiveness (in comparison to a therapy dog) in eliciting and maintaining appropriately social behaviors over time is unclear for children and adults without disabilities.

Moreover, more detailed behavioral analyses, particularly taking into account the behaviors of the interactive partner, such as AIBO, may reveal more about the promise and limits of robotic pets as interactive partners. Living dogs, who have shared a common environment with humans for at least 10,000 years, are highly attuned to human social cues and emotions (Udell & Wynne, 2008). To date, robotic dogs are programmed to exhibit only a small subset of the human-directed social bids and responses that living dogs possess. We need more comparative data on an individual's responsiveness after a dog (robot or living) social bid, as well as dog responsiveness to human social bid. For example, when a child makes a social bid (i.e., speaks to AIBO, offers a ball, approaches AIBO), what is the probability that the robotic dog would respond contingently, promptly, and appropriately? Similarly, when the child perceives that AIBO is making a social bid (through apparent gaze direction or approach), what is the probability that the child will respond and how? In sum, how reciprocal are interactions with robotic pets, in comparison with living pets? Kerepesi et al. (2006) documented less structured behavioral interactions with AIBO compared to a Cairn terrier, suggesting that robotic dog technology may be less effective than living dogs in supporting reciprocal and responsive interactions. If so, this might challenge the integration of robotic pets into therapy since appropriate contingent responsiveness is itself a therapeutic tool (Fine, 2006).

How Children's Characteristics Predict Judgments, Emotions, or Behavior toward AIBO and a Living Dog

There is remarkable developmental continuity, from early childhood on, in human attachment to living pets and in interest in other animals (Melson, 2001). At the same time, as children develop cognitively, there are age-related changes in conceptions about biology (Inagaki & Hatano, 2002) as well as attitudes about animals and nature (Kahn, 2002; Myers & Saunders, 2002). With respect to gender differences, in studies of the human–companion animal bond and of attitudes toward nature and animals more generally, differences between males and females are neither systematic nor large (Beck & Katcher, 1996; Kahn, 1999; Melson, 2001). Individual differences in responsiveness to animal-assisted interventions have been found, however. In general, individuals with prior involvement in and interest in animals may benefit more from an animal-assisted intervention than other participants (Friedmann & Tsai, 2001; Holcomb et al., 1997).

In the two studies of children, the Preschool Study and the Developmental Study, we recruited equal numbers of boys and girls within each age group, to test whether boys and girls differ in their behaviors toward and ideas about the robotic dog AIBO. In the Developmental study, we divided the sample into three age groups—7–9 years, 10–12 years; 13–15 years—to test for age differences. Finally, the study of school-aged children examined two variables tapping prior interest and involvement—pet attachment and technology involvement—as predictors of responses to either a robotic or unfamiliar living dog.

Age group and gender. Taken together, our three studies span early childhood to adulthood. Although the studies are cross-sectional, their results may generate hypotheses about possible developmental change and continuity in responses to robotic pets. In both the Preschool Study and Developmental Study, very few gender or age group differences were found in responses to the robotic dog. (In the Discussion Forum Study, postings could not be reliably identified in terms of gender or age and hence were excluded from analysis.) Out of 36 questions asking the child to affirm or deny AIBO's biological, mental, social, and moral standing characteristics, only seven questions showed age group differences. In all cases, children were less likely to affirm (say "yes") with advancing age. However, all seven questions showing age group differences had relatively complex syntax (for example, "If you were home alone, would you feel better with AIBO?"), raising the possibility of age-related differences in understanding. When the results for preschoolers are compared with those for the 7–15-year-olds, it appears that older children are less likely to endorse biological attributes, but there are no age differences in other domains. (No statistical comparisons across studies were conducted.)

Similarly, boys and girls do not appear to differ in verbal or behavioral responses toward AIBO (or toward a living or stuffed dog). There were no sex differences in preschoolers' perceptions of or behaviors toward AIBO. In the study of 7–15-year-olds, there were only two significant ($p < .05$) differences (out of 39 comparisons) between males and females in their responses about AIBO's characteristics; females were more likely to think AIBO had a stomach (34% vs. 12%)—a question in the biological domain—and that AIBO could understand you (61% vs. 29%)—a question in the mental domain. Similarly, out of 68 behavioral comparisons, only two showed sex differences; females were more likely to show apprehension toward AIBO ($p < .02$) or startle at AIBO ($p < .04$). (These two behaviors occurred overall at low frequency, less than once per play session.) Given the large number of male–female comparisons, these findings may well have been due to chance.

Pet attachment and technology involvement. It is plausible that children's prior experience with living animals or technology might affect their ideas about or behaviors toward unfamiliar living or robotic dogs. We hypothesized that children with higher attachment toward their own companion animals might respond differently to either target dog. (A few participating children volunteered "I love dogs" while we were orienting them to the study and soliciting informed consent.) Similarly, we reasoned that children who were especially involved with technology at home and at school (for example, frequent users of computers) might differ from other children in their encounters with the unfamiliar technology of a robotic dog such as AIBO.

In the study of 7–15-year-olds, therefore, we assessed pet attachment (almost all children had or previously had had a pet) as well as technology involvement and related these sources of individual variation to both cognitions about and behavior toward each type of dog. We present the results in detail, since they have not been reported elsewhere.

Each child filled out a background questionnaire after completing the interviews with both AIBO and the live dog. (An interviewer assisted children who were under 10 years of age by reading aloud each item.) Pet attachment was assessed with the Lexington Attachment to Pets Scale (LAPS; Johnson, Garrity, & Stallones, 1992), a 23-item measure, with each item scored from 1 (*strongly disagree*) to 4 (*strongly agree*). (Two items are reverse scored.) Sample items are "My pet is my best friend", and "I love my pet because it never judges me." Thus, higher scores reflect greater attachment to one's pet. Scores were averaged to yield a Pet Attachment Score. The LAPS measure has acceptable reliability and validity and is widely used in studies of HCAB. LAPS scores ranged from 1.5 to 4.00 ($M = 3.23$, $SD = .45$) indicating moderate to high attachment for most children. Pet attachment did not vary by gender or age group.

A measure of technology involvement was created from responses in the questionnaire. Specifically, the child rated each of eight home technological items (e.g., computer, television, DVD, PlayStation) from 0 (*do not have/never use*) to 10 (*use all the time*). In addition, one item, Use of School computer, was also rated in a similar manner. These items were averaged to yield a Technology Involvement Score, with a possible range of 0–10. The actual range obtained was 0–8 ($M = 4.28$, $SD = 1.63$), indicating a normal distribution. An Age Group × Gender ANOVA found a significant Age group effect, $F = 3.32$, $p < .04$; 13–15-year-olds were more technologically involved than 7–12-year-old children. Pet attachment and technology involvement were uncorrelated ($r = .13$).

In the Developmental Study, we tested whether pet attachment or technology involvement predicted perceptions of a robotic or unfamiliar living dog (the other two studies did not assess these variables). A series of simultaneous regressions was conducted with the following dependent variables: affirms biology, mental, sociability, moral standing; negates biology, mental, sociability, or moral standing, for perceptions of AIBO and for perceptions of the living dog. Pet attachment and technology involvement were entered after Age. Models for perceptions of the living dog but not of AIBO were significant, specifically those predicting negation of mental states, $F = 3.03$, $p < .05$, affirmation of moral standing, $F = 3.56$, $p < .04$, and negation of moral standing, $F = 6.18$, $p < .004$. Specifically, technological involvement predicted negation or denial of mental states of the living dog, adjusted $R^2 = .096$, $p < .05$, and of moral standing of the living dog, adjusted $R^2 = .18$, $p < .002$. Pet attachment predicted affirmation of moral standing of the living dog, adjusted $R^2 = .11$, $p < .02$. Thus, attachment to one's own pet appeared to sensitize children to the mental life and moral standing of the unfamiliar living dog, while greater technological involvement appeared to have the opposite effect.

The two predictor variables (after controlling for age) were also used to test whether they explained any of the variance in behaviors toward AIBO and toward the living dog. Again, only models for behaviors toward the living dog (not toward AIBO) were significant, specifically for verbal engagement, $F = 3.43$, $p < .04$, and ball offer, $F = 6.69$, $p < .002$. Pet attachment predicted more verbalization, including greetings, commands, and questions, adjusted $R^2 = .11$, $p < .03$, but *fewer* ball offers to the living dog, adjusted $R^2 = .19$, $p < .001$. The last finding is not surprising, because ball play with the living dog may have seemed to children more difficult in the restricted playroom space. Some children, however, presented the ball for the dog to take into its mouth, or smell.

In general, neither pet attachment nor technology involvement predicted any ideas about or behavior toward the robotic pet. These two indicators of prior involvement and interest did, however, modestly predict ideas and behavior toward the unfamiliar living dog. However, even here, only a few regression models were significant, and the amount of variance predicted was modest. Nonetheless, the results confirm that individual variations in experience with and interest in animals, especially dogs, may play a role in how children respond to AAT or intervention.

Limitations of AIBO Research

Because the three studies described here are not directly comparable, one must be cautious in deriving conclusions based on comparing and contrasting their data. However, we argue that examining cognitions and behaviors across three distinct but related studies is helpful in generating hypotheses about how human–robot dog and human–living dog interactions and interventions may be similar and different. In addition, the nascent field of robotic pet studies is at the stage where descriptive studies and hypothesis generation may be most useful. Among the limitations of the studies presented here are the following: (1) the observations and understandings reflect "snapshots" not longitudinal data that explore dynamic changes in robot–human interaction over time; (2) variations in robot dog, living dog, and human participant are not fully explored; (3) the effect of children's ownership of a dog (robot and living) on their behaviors and cognitions is not assessed.

Implications for the Human–Animal Bond and for Human Relationships with Personified Technologies

Based on the Developmental Study, there is evidence that a robotic pet—at least as currently implemented in AIBO—is a mediocre substitute for its living counterpart. For example, when compared directly with a friendly but unfamiliar living dog, AIBO was viewed as lacking across all four domains: biological, mental, social, and moral. When children were observed actually interacting with AIBO, as compared to a living dog, the robotic dog was treated more like an artifact and less like a social partner. Children who were very involved in computer-based technology and hence, presumably highly motivated to engage with a new technology found AIBO lacking, when compared to a living dog.

Nonetheless, across all three studies, there was also ample evidence that children and adults often treated AIBO as if it were a living dog. Adults owning AIBO developed attachment and often treated the robotic dog as a social companion. In the Preschool and Developmental Studies, children with only an initial and brief play period with AIBO accorded the robotic dog many of the mental and social features of a living dog, even when they did not attribute biology to the robot. These findings held across a range of ages, and for both boys and girls, and did not vary by a child's attachment to a pet at home or by involvement in computer technology at home or at school. Thus, despite AIBO's gray metal body, flashing lights, and musical sounds, the dog's shape, movements, and interactive capacities were enough to approximate (but not match) affiliative behaviors and cognitions normally directed toward living dogs.

In the Developmental Study, following the play sessions and interviews, we asked each child: "If you were designing a robot dog, what would you do to make it better? What would you never design into the robot?" Content analysis of responses revealed two major themes. In response to the first question, many children mentioned the addition of fur, so that the robotic dog would be softer, more cuddly, and more "lifelike." It is possible, however, that making the appearance of an animal robot more animal-like (e.g., by adding fur) without correspondingly increasing its animal-like interactive capabilities, would actually decrease a person's engagement with the robotic dog. A similar phenomenon, known in the robotics literature as the *uncanny valley* (Dautenhahn, 2003; MacDorman, 2005), has been shown to arise when people interact with a humanoid robot whose appearance outpaces its capabilities, resulting in people's aversive reactions. In response to the second question, many children said that robotic pets should never have sharp claws or teeth, should never behave aggressively, and should never hurt others. Both sets of responses indicate that children's ideas about living pets may be mapped onto the design of robotic pets. Thus, because children experience (most) living dogs as furry, they wish for a fur-covered robot; and because they may have experienced dog bites or aggressive dogs, or been warned about the need to approach unfamiliar dogs carefully, children are concerned with the possibility that robotic dogs might harm people.

The tendency to anthropomorphize artifacts is easily triggered (Nass & Moon, 2000; Reeves & Nass, 1998). While it remains unclear exactly what features of a robot maximize this tendency, Lee, Park, and Song (2005) found that adults who interacted with a version of AIBO with software such that the AIBO seemingly developed over time, and in response to human behaviors, perceived AIBO as more socially present, than did adults who interacted with a "fully developed" AIBO. The two studies of children used AIBOs with software of a fully developed or "mature" robotic dog. Perhaps replication of some of our methods over a longer period of interaction with a "developing" AIBO might yield differing results.

That said, our studies suggest that the idea that people anthropomorphize robots may need to be amended. For as robots of today (and the future) become increasingly social—autonomous (insofar as they initiate action), adaptive (act in response to their physical and social environment), personified (convey an animal or human persona), and embodied (the computation is embedded in the artifacts rather than just in desktop computers or peripherals)—it seems likely that children and adults will not only interact with them "as if" they were social others, but begin to feel about them and treat them as having life, mental states, sociality, and moral worth.

What do such views mean? That is an open question. The human tendency to project feelings and attributes onto objects through pretense or metaphor may be operating. Alternately, people may develop relationships with robotic animals in a process similar to "the willing suspension of disbelief," the state we enter as we immerse ourselves in an absorbing novel, play, or movie. Another possibility is that a new technological genre is emerging that will increasingly challenge our existing cognitive categories, between for example "alive or not alive," "animate or inanimate," "having agency or not," or "being a social other or not." Indeed, an even stronger proposition is that this technological genre will emerge as a new ontological category (Kahn et al., 2006). It will not simply be an additive composition of, for example, a portion of alive and a portion of not alive. Rather, in the way that mixing red and yellow leads to the entirely new color orange (which we do not experience as either of its constituent parts), so might people—and especially young children as they construct categories of knowledge based on interaction—experience the various attributes of personified technologies of the future in new ways. If that is the case, then it is not surprising that researchers (ourselves included) encounter difficulties as we ask questions (e.g., Is AIBO alive or not alive?) based on the only language and categories we know to investigate an entity where the answers may be "neither and both."

Social Issues

Studies of AIBO reveal both the limits and promise of robot pets in relation to human–animal interaction. The findings suggest caution in assuming that a robot pet or RAA can be an effective substitute for a living companion animal or AAT. Social policies that might make robot pets more accessible and affordable (e.g., to socially isolated seniors living in institutional settings) should be weighed against policies making living animals more accessible and affordable.

Moreover, one cannot rule out the possibility that increasing exposure to mediated interaction with animals, through robotics, virtual reality and other media, may come at the expense of direct engagement with living animals. Whether children will suffer from "nature-deficit disorder" as a result, as Louv (2005) warns, is unclear, but the social consequences, especially for children, of reduced engagement with the natural world should be an urgent focus of study.

To conclude, greater understanding of human–robot interactions should help pinpoint those interventions where such interactions may be optimal. For example, children with autism-spectrum disorders appear to sustain attentiveness to a humanoid robot, making RAA a useful adjunct in therapy with these disorders (Werry & Dautenhahn, 1999). Finally, in situations where living animals are not allowed, (e.g., in intensive care units), robotic animals appear to have beneficial effects on children's adjustment comparable to those of living animals (Yokoyama, personal communication). Robotic pets may ultimately have a place within the complex relationships that humans have with animals.

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