

Toward Understanding Children's and Adults' Encounters with Social Robots

Gail F. Melson,¹ Peter H. Kahn, Jr.,² Alan Beck,³ and Batya Friedman⁴

¹Department of Child Development & Family Studies, Purdue University
101 Gates Road, West Lafayette, IN 47907 melsong@purdue.edu

²Department of Psychology, Box 351525, University of Washington,
Seattle Washington, 98195-1525. pkahn@u.washington.edu

³Center for the Human-Animal Bond, Purdue University,
West Lafayette, IN 47907. abeck@purdue.edu

⁴The Information School, Box 352840, University of Washington
Seattle, Washington, 98195-2840 batya@u.washington.edu

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Abstract

While the design of social robots, has engaged researchers for some time, only recently have the human implications of interaction with such robots been considered. In this paper, we address how children and adults behave toward and think about the social robot AIBO. Our work is informed by a conceptual framework that draws on constructs within cognitive psychology: the *essentialist theory* of cognitive development and *scripts*. At the same time, our research challenges assumptions of both the essentialist theory of cognitive development and scripts and argues for a more dynamic and complex formulation of these constructs. Four studies of children and adults interacting with AIBO conducted by our research team serve to illustrate aspects of this framework. We close by suggesting further questions raised by this work.

Reeves and Nass (2002) have proposed that “individuals’ interactions with computers, television, and new media are *fundamentally social and natural*, just like interactions in real life” (p. 5 authors’ emphasis). The new media of social robots are of special interest in this regard, since they particularly evoke social and affective human responses (Breazeal, 2003; Fong, Nourbakhsh, & Dautenhahn, 2003; Lee, Park, and Song 2005). In this paper, we suggest a conceptual framework for understanding human responses to social robots in general, and to the social robot AIBO, in particular. This conceptual framework draws on the constructs of the essentialist theory of cognitive development, particularly as elaborated by Susan Gelman (2004) and her colleagues, as well as the construct of cognitive script (Shank and Abelson 2002). However, it places these ideas within a dynamic constructivist systems perspective (Melson, forthcoming) in which

individuals construct the meaning of human-robot interactions over time as they experience these interactions. The resulting ‘constructions,’ evident in behavior, cognitions, and emotions related to the social robot, are the product of individual human and robot characteristics and history as well as the context and history of interaction. Hence, like all dynamic systems, HRI properties are emergent and not fully determined a priori.

A Framework for Understanding Human Responses to Social Robots

Essentialist Theory of Cognition

In the essentialist theory of cognition (Gelman 2004), once an object is identified as belonging to a particular domain, essentialist beliefs lead one to infer ‘essences,’ i.e., distinct unseen properties that reflect the underlying nature that imparts category identity. For example, five year olds will infer bones as internal parts of an unfamiliar object labeled as an “animal” but batteries as internal parts of an unfamiliar object labeled as a “machine” (Gottfried and Gelman 2005). Thus, a key feature of the essentialist view of cognitive development is category assignment. When encountering an unfamiliar social robot, individuals ask themselves (usually unconsciously): “What type of object is this?” The answer to this question allows one to infer unseen category attributes (e.g., if a computer like machine, it probably has batteries or power source, microchips, and sensors). However, essentialist theory assumes ontologically a limited and presumably fixed number of broad essences—biological, psychological, or artifactual—into

which one slots unfamiliar objects. In this sense, essentialist theory divides its ontology into predetermined Platonic categories. To forecast our argument, encounters with social robots may challenge such an ontological accounting, showing evidence of category boundaries that shift, blur, and overlap. Sociable robots may prompt humans to construct new ontological categories to make sense of their interactions with them.

Scripts

In addition, the construct of *script* suggests that category assignment by determining the ‘essence’ of a new object is linked to behaviors, cognitions and emotions associated with objects in that category. Cognitive scripts are representational schemes that encode behaviors, thoughts and emotions embedded in recurring contexts. For example, we have cognitive scripts for going to the grocery store, having a restaurant meal, having friends over for drinks, etc. A cognitive script for such situations includes perceptions of the other (the grocery clerk, the waiter, the friend), sequential routines (at a restaurant, being seated, ordering food, eating, and paying the bill), and appropriate behaviors and emotional expressions (hugging the friend but not the waiter).

Research within the essentialist theory paradigm suggests that the essence-script association may occur deductively or inductively. Deductively, judgment of the essence of an object leads to associated scripts, while inductively, behaviors, cognitions and emotions evoked toward an object lead to inferences about its unseen essence.

Both children and adults may bring scripts developed through experience with living and non-living others and objects and apply them to encounters with unfamiliar social robots. For example, in the case of AIBO, a social robot with the shape of a dog and equipped with a repertoire of ‘dog-like’ behaviors, humans may use scripts—behaviors, ideas and feelings—associated with relating to a pet dog. After all, nearly 40% of all U. S. households contain dogs (APPMA 2005), and dog owners overwhelmingly identify their animals as family members. Children are especially likely to grow up with dogs and other pets, since pet ownership is disproportionately high in households with children under 18 years of age. Nearly all children and adults, including those without pets, have well established scripts for playing with, caring for, and just living with dogs. Alternately (or in addition), AIBO might evoke scripts for playing with a metal toy with flashing lights, musical sounds, and autonomously moving parts. Such a script might be familiar especially to children who have experience with Furby and other such toy animals.

Dynamic Change in Essentialist Beliefs and Scripts

However, essentialist reasoning and its associated scripts are likely to affect only initial encounters with an unfamiliar social robot. We posit that this is because such cognitive processes are dynamically changing as the individual acquires experience with a social robot. A constructivist interpretation of essentialist reasoning and scripts allows for the elaboration of new essences and scripts. This view is consistent with the cognitive processes of assimilation, disequilibrium, accommodation, and equilibrium central to Piagetian theory (Piaget 1952). Humans use the Piagetian process of *assimilation* to make sense of initial encounters with social robots. Assimilation involves application of existing cognitive schemes or constructs (the essences and scripts), acquired through past experience, to make sense of an unfamiliar situation. For example, upon first encounter with AIBO, one might think, “AIBO is like a dog”; or “AIBO is like a toy humanoid robot I play with at home”. In the course of interaction, however, humans may find the robot acting in unfamiliar ways, so that their existing cognitive schemes cannot fully account for the interaction. This would create cognitive *disequilibrium* and prompt the development of new schemes or categories of thought, a process Piaget termed *accommodation*. The resulting new cognitive representations return the cognitive system to *equilibrium*. The processes of assimilation/disequilibrium/accommodation provide the underlying mechanisms of dynamic change in understanding social robots and interacting with them.

Application of essentialist theory and the construct of script suggest that humans may assimilate initial judgments about and interaction with an unfamiliar social robot to essences and associated scripts involving interaction with other humans, non-human animals, toys or machines. By observing and interviewing humans of different ages and experience with particular social robots, we assessed both their initial judgments about essences and scripts and modifications in both as they interact with the social robot. Specifically, we were interested in the extent to which humans think about and behave toward AIBO as: (1) an artifact; (2) a biological entity; (3) a psychological agent, with intentions, desires, and feelings; (4) a social companion capable of friendship and social support; and (4) a moral being, with claims to be treated justly and kindly.

To illustrate our framework, we draw on studies of human behavior with and ideas about Sony’s AIBO conducted by members of our research group. These studies consist of (1) a content analysis of 3 months of discourse (6,438 spontaneous postings) on AIBO discussion forums (Friedman, Kahn and Hagman 2003); (2) observations and interviews with 80 3-5 year old children who interacted with either AIBO or a toy stuffed dog (Kahn et al in press); observations and interviews with 72 children ages seven to

fifteen years old interacting with both AIBO and a live dog, an Australian Shepherd bitch (Melson et al 2004); and (4) qualitative case studies of 13 elderly women each of whom was given an AIBO to live with for 6 weeks (Beck et al 2004). Studies 2-4 employed AIBOs version 210 with 64 bit RISC processor and 16 megabytes removable memory stick. AIBO has sensors in the head, chin, back and feet and can signal emotion-like internal states by flashing lights and making musical sounds. The AIBOs in studies 2-4 were of grey metal, with software of a 'fully mature' AIBO.

Judging the Essence of AIBO

We explored category assignment of AIBO in studies 2-4 in several ways. One was a card sort task developed for these studies, in which 4" x 6" color photographs of a humanoid robot, a stuffed dog, a desktop computer, and a real dog were presented in all pair-wise comparisons with a photograph of AIBO always as the anchor card. In the child studies, the card sort task was conducted following a free play interaction period and interview about AIBO, while in the case studies of elderly women, the task was conducted once prior and once after the 6 week period living with AIBO. During the card sort task, each child or adult was asked: "Is AIBO more like [one object] or [the other object]?" Thus, each person responded to a total of six pair-wise comparisons: robot/computer; robot/real dog; computer/real dog; computer/stuffed dog; and stuffed dog/real dog. We found that preschoolers, older children and the elderly tended to reject the desktop computer in favor of the other objects in relevant comparisons. The youngest children were evenly split when asked to choose humanoid robot vs. stuffed dog; robot vs. real dog, and real dog vs. stuffed dog. However, older children (7-15 years) consistently selected the humanoid robot over other comparison objects, while the elderly individuals thought that both the humanoid robot and the real dog were more similar to AIBO, while the stuffed dog and computer were less similar.

The card sort results suggest that the embodied quality of a social robot like AIBO may have skewed judgments away from desktop computers and toward other embodied forms. For some, embodiment in dog shape (with some 'dog-like' movements) may pull toward comparisons with real dogs. For the elderly individuals participating in our case study, autonomous movement may have been important in their judgments of AIBO as more similar to those comparison objects that are capable of self-initiated movement.

Another source of data about category membership was children's justifications for their judgments about AIBO in studies 2 and 3. In addition to the card sort task, preschoolers were asked 34 questions about characteristics of AIBO (e.g., "Is AIBO alive?") or evaluations of AIBO

(e.g., "Do you like AIBO?"), each of which could be answered in the affirmative or negative. Following each response, follow-up probes (e.g. "How do you know?" "Why?") asked for justifications. Similarly, in the study of children ages 7-15 years, probes were used to elicit justifications for affirmations or negations to each of 38 questions about AIBO. Content analysis of these justifications showed that, in both studies, some children explicitly likened AIBO to a real animal or human being. For example, 12% of preschoolers who judged AIBO to have animacy (e.g., is alive, can die, is real) explained that it was because AIBO was "like" a real animal. In the study of older children, 82% reasoned at least once that AIBO "is" or "is like" an animal or human in explaining their judgments. At the same time, children often explained their judgments by referring to AIBO's essence as a robot, toy or artifact. For example, one 15 year old male responded to the question: "Do you like AIBO?" as follows: "I don't know. I'm not really a gadget person. I'm not saying somebody wouldn't, but I don't personally. I see this as more of a toy than anything."

Scripts for AIBO

We conceptualize the scripts that individuals may bring to interaction with AIBO in terms of both behaviors and cognitions or ideas. With respect to behaviors, because AIBO is designed to mimic some behaviors (tail wag, ear, head and leg movements) of living dogs, routines for interacting with dogs may be initially evoked. Thus, children or adults might pet and stroke AIBO, scratch AIBO under the chin and behind the ears, offer AIBO a ball, and ask AIBO to 'fetch,' 'sit' and 'stay.' However, since AIBO is grey metal, has flashing lights and musical sounds, humans might poke, prod, shake and explore AIBO as an artifact or machine, trying to find out how AIBO 'works.' With respect to cognitions, we expected that children or adults would develop initial ideas about AIBO's characteristics and themselves in relation to AIBO. These cognitive elements of a script toward AIBO are hypothesized to be similar to the attachment theory construct of *internal working model*, the cognitive representation of self-in-representation-with-other (Ainsworth 1979).

We found behavioral evidence for scripts related both to artifacts and to real dogs. Thus, both preschoolers and older children poked and prodded AIBO, exploring it as an artifact. For example, during a 20-25 min. unstructured play session with AIBO, preschoolers explored AIBO as an artifact on average 2.76 times. However, the same preschoolers also petted, kissed, and hugged AIBO, scratched AIBO gently behind the ears or under the chin, presented their hand, offered a ball, gave commands, and greeted AIBO as a living dog. On average, affectionate behaviors occurred 3.67 times, while attempts at reciprocity (verbal commands, ball offers, hand motions) occurred 8.54 times.

Among older children, whose behaviors were coded during a shorter, 5 min. play session with AIBO, exploration as artifact occurred an average of 3.57 times, while affectionate behaviors occurred 3.83 times, and attempts at reciprocity 17.60 times. During the short play session, children spoke to AIBO on average 5.51 times. (The context for coding behaviors differed somewhat in the two studies of children. In the study of preschoolers, behaviors were coded during a semi-structured interview, with an interviewer present. In the study of older children, spontaneous behaviors were coded during a five minute unstructured play period, in which only the child, AIBO and a red ball were present in the playroom.)

Scripts are also cognitive and may be affectively charged. To determine the attributes that AIBO was thought to possess and the perceived quality of interactions with AIBO, we asked both children and adults (studies 2-4) whether AIBO possesses a biology, psychology, social companion status, and moral standing. For example, is AIBO alive (biology); does AIBO think and feel (psychology); can AIBO be a good friend (social companion); and does AIBO have rights and deserve kind, fair, and just treatment (moral standing). To analyze reasoning, we also asked them to explain why they believed that AIBO possessed or lacked these biological, psychological, social, and moral characteristics (see discussion of justifications above). The content analysis of discussion forum postings (study 1) assessed the percentage of participants who spontaneously affirmed or denied AIBO's artifactual, biological, psychological, social and moral attributes, but did not provide data on justifications for these judgments.

Attribution of biological properties to AIBO varied by group: 46% for preschoolers, 22% for older children and 47% among adult AIBO owners. Affirmations of psychology and mental states, on the other hand, predominated in all three studies: 66% preschoolers, 56% older children, and 60% adult AIBO owners. Similarly, across studies, there was strong affirmation of AIBO as a social companion: 76% preschoolers, 70% older children, and 59% discussion forum entries. Finally, there was an interesting pattern, whereby children perceived that AIBO has moral standing (63% preschoolers, 76% older children) but adult AIBO owners, at least in their discussion forum postings, did not (12%). Overall, while AIBO was recognized as an artifact, the social robot was nonetheless endowed with biological, psychological, social, and (at least for children) some moral properties.

Analysis of children's justifications for their attributions of various characteristics to AIBO supports this conclusion. For example, in the study of older children, only one child failed to cite AIBO's essence as an artifact in support of a judgment, and on average, children mentioned artifactual category membership 11.2 times, using this justification for nearly one-third of their judgments. However,

99% of children also cited AIBO's possession of a biology as justification for at least one judgment, and on average, used biological justifications 4.6 times. Similarly, children justified judgments about AIBO in terms of its status as a psychological and mental agent, on average 6.2 times and as a moral being an average of four times. This supports the view that embodied social robots like AIBO may give rise to new ontological categories, artifacts that appear to think and feel, can be friends and at least potentially lay some moral claims for kind, fair and just treatment.

There was evidence of this kind of emergent representation of AIBO, particularly among the 10-15 year olds in our study of school-age children. For example, one 14 year old answered the question: "Is AIBO alive or not alive?" by saying: "In the mechanical sense, yes. He's a robot dog and he doesn't have the characteristics of actual living things, but mechanically he's alive."

Our conceptual framework suggests that initial judgments of essences and scripts are likely to dynamically change as individuals gain experience with a social robot. We find preliminary evidence of this in the case studies of elderly individuals, who after 6 weeks with AIBO, were more likely to describe the robot as a "dog" than a "machine" and to identify its needs as "attention" and "love" rather than "batteries."

Emergent Properties of Human Interaction with AIBO

A dynamic systems approach suggests that individual characteristics of human and robot as well as contextual effects constitute a system with emergent properties. These elements are hypothesized to yield patterns of interaction and human understandings that cannot be fully specified a priori (Anolli et al 2005).

Human variability

Humans bring varying levels of interest and experience with mediated social interactions through computers and other media as well as varying experience with robots. In our study of 7- to 15 year olds, we collected background information on each child's family characteristics, technology involvement, and pet involvement (almost all children had pets). In this study, each child (and independently one parent) self-reported technology involvement through questionnaire responses about the presence in the home of technologies such as computers, television, video/DVD, PDAs, videogames, and robotic toys. For each technology available, the child (and parent) estimated regular use by circling the appropriate number (0="never use;" 10="use all the time"). Children also reported computer use when at school. Two self-report measures assessed pet involvement: one was a child self-report on regular time spent in various pet care activities (feeding,

walking, grooming, playing), the other, a measure of the child's emotional attachment to a pet. We found that a composite technology involvement measure based on child self-report predicted children's judgments that AIBO did not have mental states or psychological agency and that AIBO did not have moral standing, while attachment to one's pet predicted affirmation of AIBO as having moral standing (Melson et al unpublished manuscript). Thus, a child's technology involvement and pet attachment predicted readiness or reluctance to view AIBO as a psychological entity and part of their moral universe. These results are consistent with findings that 10-11 year old Japanese children who are more interested in friendship and less interested in mechanical objects sustain longer friendly interactions with a humanoid robot (Kanda et. al. 2004c).

Given their broad importance in development, gender and age differences in behaviors toward or judgments about AIBO are of interest. In the studies under consideration here, we found no gender differences and modest evidence of age differences. Younger children (7-9 years of age) viewed AIBO as more of a social companion and more deserving of moral regard than older children (10-15 years of age).

In general, the contribution of individual human differences to HRI remains an open question. In our studies of children, there was attenuated variability in the predictor variables. In addition, individual differences may more strongly predict interaction and judgments over a longer interaction period, rather than an initial encounter. There is also the issue of which individual variables might be most salient for specific types of interactions with robots.

Robot variability

As with any interaction, a social robot's behavior and characteristics during an interaction will influence human behavior toward and judgments about it. In the study of preschoolers, child behaviors were coded in terms of their co-occurrence with AIBO-initiated behaviors, with "co-occurrence" defined as a behavior occurring within 5 seconds following an AIBO behavior. Virtually all (99%) apprehensive behaviors occurred after AIBO initiated a behavior, particularly when AIBO moved and approached a child. Children most frequently initiated reciprocal interactions (e.g., trying to 'play ball' with AIBO) after AIBO initiated behaviors, such as approach, kick ball, or head butt ball.

Various characteristics of AIBO's physical embodiment may evoke different responses. Participants in the study of 7-15 year olds often justified their judgments that AIBO was a robot or machine by citing its metal and grey color. At the end of the interview, each child was asked: "If you were designing a robot, what would you do differently?" The most frequent responses referred to physical features

(make soft, put on fur) and behaviors (make more lifelike). Other research finds that both children and adults are sensitive to subtle variations in robot appearance and behavior. For example, a humanoid robot's eye contact, contingency, autonomy and well coordinated movements are strongly associated with adults' positive evaluations (Yamaoka et. al 2006; Kanda et. al. 2004b).

Finally attributed characteristics, such as gender, ethnicity, age, or personality, which may be manipulated experimentally, may influence both behaviors and cognitions. A basic principle of human relationships posits that perceived similarity—the "like me" judgment—predicts positive interaction, relationship maintenance and liking. As applied to HRI, this principle suggests that perceived similarity to a robot, or even the establishment of some common ground, would have similar outcomes. Consistent with this is research showing that Japanese children who already know some English learned more English from an English speaking Robovie humanoid robot than did their peers who had no prior knowledge of English (Kanda et al. 2004a).

Contextual variability

Contextual factors also are part of the system within which HRI takes place. As Lee, Park and Song (2005) found, college students who individually interact with AIBO feel closer to the social robot than peers who interact in groups of 4-6 students. In the study of 13 elderly women who each lived with an AIBO for six weeks, qualitative analysis of responses to the question: "What did you like to do with AIBO?" identified the theme—show it to others—along with talk, hold and pet. In the context of an assisted living facility, AIBO appeared to serve as an object of shared attention (Dautenhahn 2003) and have social lubrication effects similar to those documented for children and adults in the presence of friendly dogs as well as small pets like rabbits and hamsters (Hunt, Hart, and Gomulkiewicz 1992; Mader, Hart, and Bergin 1989). Such effects, which increase social acknowledgments from others, may be related to the decrease in self-reported depression and increase in life satisfaction reported by study participants after the six weeks with AIBO.

Implications

While our understanding of human interactions with a social robot is only beginning to take shape, it appears that both children and adults bring to initial encounters some judgments of its essences and with that scripts for interacting with it. But an important question is the following: How, through their initial interactions, do individuals modify their initial attributions of essences and scripts, and construct new concepts of and relationships with social robots? Indeed, is it possible that a new technological

genre may be emerging that challenges traditional ontological categories (e.g., between animate and inanimate). If so, then it may be that the English language is not yet well equipped to characterize or talk about this genre (Kahn et al 2004). As one of our study participants, an 11 year old boy said, when asked if AIBO had a soul: "Not really, but...a mechanical soul." That is not very precise language. It may be that as social robots increasingly mimic aspects of biological life, such as agency, autonomy, and sociality, that new terms will arise that characterize this increasingly novel entity.

The research we presented in this paper also should give one pause about the nature of the interactions we are designing into personified computational systems. If it is the case, for example, that people will develop rather robust social relationships with social robots, but not accord them full moral status, then we may be creating one-sided interactions, not unlike a person might have with a therapist, a servant, or even a slave. In turn, is it possible that increasing one's interactions with social robots will lead people to see other humans or animals as "robot-like"? That is as equally problematic. Both concerns, we suggest, should be part of the research and design space of the communities in artificial intelligence, machine learning and adaptive systems, robotics, and android science.

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References

Ainsworth, M. 1979. Attachment as Related to Mother-Infant Interaction. In R. Hinde, and J. Rosenblatt, eds. *Advances in the Study of Behavior*. New York: Academic Press.

Anolli, L., Duncan, S. Jr., Magnussion, M. S., and Riva, G. eds. 2005. *The Hidden Structure of Interaction: From Neurons to Culture Patterns. Volume 7 Emerging Communication: Studies in New Technologies and Practices in Communication*.

APPMA. 2005. *2005-2006 APPMA National Pet Owners Survey*. Greenwich, CT: American Pet Products Manufacturers Association, Inc.

Beck, A. M., Edwards, N., Kahn, P. H. Jr., and Friedman, B. 2004. Robotic Pets as Perceived Companions for Older

Adults. *Tenth International Conference on Human-Animal Interaction*. Glasgow, Scotland.

Breazeal, C. 2002. *Designing Sociable Robots: Intelligent Robotics and Autonomous Agents*. Cambridge, MA: MIT Press.

Breazeal, C. 2003. Toward Sociable Robots. *Robotics and Autonomous Systems* 42:167-175.

Dautenhahn, K. 2003. Roles and Functions of Robots in Human Society: Implications from Research in Autism Therapy. *Robotica* 21:443-452.

Edwards, N., Beck, A., Kahn, P. H., Jr., and Friedman, B. 2004. *Robotic Pets as Perceived Companions for Older Adults*. Paper presented at the 10th International Conference on Human-Animal Interactions. Glasgow, Scotland.

Fong, T., Nourbakhsh, I., and Dautenhahn, K. 2003. A Survey of Socially Interactive Robots. *Robotics and Autonomous Systems* 42:143-166.

Friedman, B., Kahn, P. H. Jr., and Hagman, J. 2003. Hardware Companions?—What Online AIBO Discussion Forums Reveal about the Human-Robotic Relationship. *Proceedings of the Conference on Human Factors in Computing Systems*, 273-280. New York, NY: Association for Computing Machinery.

Gelman, S. A. 2004. Psychological Essentialism in Children. *Trends in Cognitive Sciences* 8: 404-409.

Gottfried, G. M., and Gelman, S. A. 2005. Developing Domain-Specific Causal-Explanatory Frameworks: The Role of Insides and Immanence." *Cognitive Development* 20:137-158.

Hunt, S. J., Hart, L. A., and Gomulkiewicz, R. 1992. The Role of Small Animals in Social Interaction between Strangers. *Journal of Social Psychology* 133:245-256.

Kahn, P. H., Jr., Freier, N. G., Friedman, B., Severson, R. L. and Feldman, E. 2004. Social and moral relationships with robotic others? *Proceedings of the 13th International Workshop on Robot and Human Interactive Communication (RO-MAN '04)* (pp. 545-550). Piscataway, NJ: Institute of Electrical and Electronics Engineers (IEEE).

Kahn, P. H. Jr., Friedman, B., Perez-Granados, D. R., and Freier, N. G. in press. Robotic Pets in the Lives of Pre-school Children. *Interaction Studies: Social Behavior and Communication in Biological and Artificial Systems*.

Kanda, T., Hirano, T., Eaton, D., and Ishiguro, H. 2004a. Interactive robots as Social Partners and Peer Tutors for

Children: A Field Trial. *Human-Computer Interaction* 19:61-84.

Kanda, T., Ishiguro, H., Imai, M., and Ono, T. 2004b. Development and Evaluation of Interactive Humanoid Robots. *Proceedings of the IEEE* 92:1839-1850.

Kanda, T., Sato, R., Saiwaki, N., and Ishiguro, H. 2004c. Friendly Social Robot That Understands Human's Friendly Relationships. *Proceedings of the 2004 IEEE/RSJ International Conference on Intelligent Robots and Systems*. Sendai, Japan.

Lee, K., Park, N., and Song, H. 2005. Can a Robot Be Perceived as a Developing Creature? *Human Communication Research* 31:538-563.

Mader, B., Hart, L. A., and Bergin, B. 1989. Social Acknowledgments for Children with Disabilities: Effects of Service Dogs. *Child Development* 60:1529-1534.

Melson, G. F. 2001. *Why the Wild Things Are: Animals in the Lives of Children*. Cambridge, MA: Harvard University Press.

Melson, G. F. Children in the Living World: Why Animals Matter for Children's Development. In A. Fogel, and S. Shanker, eds., *Human Development in the 21st Century: Visionary Policy Ideas from Systems Scientists*. Bethesda, MD: Council on Human Development. Forthcoming.

Melson, G. F., Kahn, P. H. Jr., Beck, A., Friedman, B., Roberts, T., and Garrett, E. 2004. Children's Behavior Toward and Understanding of Robotic and Living Dogs. *Tenth International Conference on Human-Animal Interactions*. Glasgow, Scotland.

Melson, G.F., Kahn, P. H., Jr., Beck, A., Friedman, B., Ko, M., and Albert, J. Predictors of children's behaviors toward and judgments about AIBO: The role of pet and technology involvement. (unpublished manuscript).

Piaget, J. 1952. *The Origins of Intelligence in Children*. New York: International Universities Press.

Read, S. J. 1987. Constructing Causal Scenarios: A Knowledge Structural Approach to Causal Reasoning. *Journal of Personality and Social Psychology* 52: 288-302.

Reeves, B., and Nass, C. 2002. *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*. Stanford, CA: CSLI Publications.

Schank, R. C., and Abelson, R. P. 2002. *Scripts, Plans, Goals, and Understanding*. Hillsdale, NJ: Erlbaum.

Yamaoka, F., Kanda, T., Ishiguro, H., and Hagita, N. 2006. How Contingent Should a Communication Robot Be? *Proceedings of HRI 06*. Salt Lake City, UT.