# Interactions With Robots: The Truths We Reveal About Ourselves

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## Keywords

human–robot interaction, uncanny valley, mind perception, anthropomorphism

## Abstract

In movies, robots are often extremely humanlike. Although these robots are not yet reality, robots are currently being used in healthcare, education, and business. Robots provide benefits such as relieving loneliness and enabling communication. Engineers are trying to build robots that look and behave like humans and thus need comprehensive knowledge not only of technology but also of human cognition, emotion, and behavior. This need is driving engineers to study human behavior toward other humans and toward robots, leading to greater understanding of how humans think, feel, and behave in these contexts, including our tendencies for mindless social behaviors, anthropomorphism, uncanny feelings toward robots, and the formation of emotional attachments. However, in considering the increased use of robots, many people have concerns about deception, privacy, job loss, safety, and the loss of human relationships. Human–robot interaction is a fascinating field and one in which psychologists have much to contribute, both to the development of robots and to the study of human behavior.

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## INTRODUCTION

Robots in science fiction movies are often humanlike. They experience emotions, express opinions, and have motives, and we relate to them easily. Few of us have seen robots in real life, and our ideas about them are often informed by what we see in movies (Broadbent et al. 2010), where robots have minds, are conscious, can love us, can kill us, and can be all but indistinguishable from us. But how close is fiction to reality? How human are robots? Can they really think and feel? Can we love them? Do they really want to take over the world?

Humans have a long history of trying to make artificial versions of ourselves. Leonardo da Vinci designed a mechanical knight in 1495 that was operated by pulleys and could sit, stand, move its arms, and raise its visor (Rosheim 2006). Another well-known example is the Turk, which was built in the late eighteenth century to appear as an automaton that could play chess but was secretly operated by a real human hiding inside its base (Thicknesse 1784). It was not until the middle of the twentieth century that Alan Turing and his contemporaries laid the foundations for modern digital computing and autonomous robots (Turing 1950). An autonomous robot is a machine that can operate and perform tasks by itself without continuous human guidance. The first robot was a digitally operated programmable arm used in the car industry in the 1950s. Since then, industrial robots have burgeoned; they often operate inside safety cages away from humans. Military robots have also been extensively developed for tasks such as surveillance, bomb disposal, and automated weaponry. These kinds of robots are largely seen as tools for humans to use. Over the past 20 years, we have seen an increase in the development of social robots, which are made to

**Autonomous robot:** a robot that can operate and perform tasks by itself without continuous human guidance interact closely with humans as artificial companions and helpers in our homes, hospitals, schools, shopping malls, and beyond. It is in this application that robots are being made to mimic humans most closely—in looks, mind, emotional expression, and behavior. It is in this area that young roboticists, inspired by the robots portrayed in science fiction, are trying to make robots just like us.

This article delves into the psychology behind our relationships with social robots. It reviews current applications of robots and research on how humans relate to robots, explores concerns about robots, and looks ahead to the future of the field. This article also highlights research on robots that has contributed to our understanding of human behavior. The further we go down the path toward making and interacting with artificial humans, the more truths we learn about ourselves. Computer scientists and engineers have conducted most of the research in this area over the past 20 years, investigating the construction of robots and testing them with humans. However, psychologists have made some important contributions to both theory and methods. Because psychologists have expert knowledge in understanding human behavior, building theoretical models, conducting social science research, and constructing valid and reliable measures, they have much to contribute. Greater involvement by psychologists will help to shape the future development of robots in socially acceptable ways.

## CURRENT APPLICATIONS OF SOCIAL ROBOTS

For someone unfamiliar with robots, the first thing to understand is that almost all the robots we see in science fiction are very much a fantasy. Even the robot in the film *Robot & Frank* (Ford 2012), which looks much like the real robot Asimo, made by Honda, has been given far greater abilities in the film than are possessed by the real Asimo. Typical robots that you might see in many robot labs across the world range from simple wheeled robots to mechanical arms, aerial drones, robots that look like animals, and robots that look like humans. **Figure 1** shows some examples of pet-like and humanlike robots.

There are many robots currently in the development phase in robotic labs across the world. Seeing social robots in real life is less common. However, autonomous robots are operating in shopping malls in Japan and Korea. Autonomous robots have also been used in kindergartens in Korea (Hyun et al. 2010). In many developed countries, autonomous robots do vacuum cleaning in houses, and there are a growing number of autonomous companion robots in retirement homes across the developed world. There is even a Japanese hotel staffed by robots, albeit with humans assisting (Rajesh 2015). Roboticists are naturally motivated to make useful robots and ones that will have commercial success. The following sections describe how social robots are currently being used.

### Healthcare Robots for Older People

The current demographic trend of increasing numbers of people aged 65 and over is placing strain on healthcare systems (Bloom et al. 2015). Robots have been proposed as one way to help meet some of the healthcare needs of older people (Robinson et al. 2014). The majority of healthcare robots are still in development and have not yet been commercialized, but research has been conducted with various prototypes. Robots are being made to assist with physical tasks (e.g., walking, fetching and carrying, and bathing), cognitive issues (e.g., reminding and playing memory games), health management (e.g., monitoring blood pressure, detecting falls, and encouraging exercise), and psychosocial issues (e.g., providing companionship and entertainment).

One of the best-known commercialized and autonomous social robots is Paro, a Japanese companion robot shaped like a baby harp seal, which can move and make seal noises in response


a
b
c
d
e
f
g
h
Take my meds
Other features
SNEEZY

to touch, light, noise, and orientation. Thousands of Paros have been sold across Europe, the United States, and Asia, mainly for use in rest homes for companionship and in dementia care for therapy. Paro has been designed to look cute, with big eyes, big eyelashes, and soft fur. One of the reasons a baby seal was chosen (rather than a more familiar animal like a cat) is that it is relatively easy to meet people's expectations of its behavior. People like to cuddle, stroke, and talk with Paro like they would with a pet animal. A randomized controlled trial found that Paro reduced loneliness and increased social interactions (i.e., talking to the robot and to other people) in a group setting in a rest home or hospital compared to other activities (Robinson et al. 2013). However, responses to Paro were mixed, with some older people liking and engaging with it and others not interacting with it (Robinson et al. 2015, 2016). Analysis of conversations that rest-home residents had with Paro revealed instances in which residents spoke about Paro knowing what was going on, having emotions, and having bodily states (e.g., Paro felt cold or had a rumbling tummy), yet the residents also spoke of Paro as an artificial object. A randomized cluster trial suggested Paro could reduce agitation and depression in people with dementia (Jøranson et al. 2015). Paro was also shown to help address individual problematic behaviors among psychogeriatric patients in a quasi-experimental study (Bemelmans et al. 2015). Paro has been well received by staff in dementia care and relatives of people with dementia (Robinson et al. 2012).

Interviews with people who had healthcare robots in their homes for 6 weeks or more reveal important themes of robot companionship and sociability (Broadbent et al. 2014, Orejana et al. 2015). Two robots, iRobi and Cafero, were used to remind people to take their medications, take blood pressure measurements and pulse oximetry, and provide entertainment and cognitive stimulation. People reported talking to the robot and rubbing its head, feeling not as alone when it was in the house, and missing the robot when it was gone. There were preliminary indications that these healthcare robots could reduce healthcare visits.

Research suggests that the appearance of robots for the care of older people should be matched to the task they perform. People preferred a fluffy robot for companionship but a more mechanical robot for reminding them to take their medication (Broadbent et al. 2009). Practicalities are important because of the size restrictions of people's rooms. The height should not be too intimidating but should be high enough to be seen easily. In interviews with residents of a retirement village, humanlikeness was perceived to be necessary only if it related to the robot's function. For example, a lifting robot need not look human but a telemedicine robot should (Broadbent et al. 2012). Many residents expressed a preference for nonhumanlike robots as they did not want them to replace humans. Voices are also important in robots, with people preferring a more humanlike voice over a more robotic-sounding voice in a healthcare robot (Tamagawa et al. 2011).

These studies show that robots can provide benefits to older people, including reducing loneliness, problematic behaviors, and depression, as well as increasing social interactions with other people. However, some staff and residents in retirement facilities have concerns that robots will take away the jobs of humans and that residents could miss out on human contact (Broadbent et al. 2012). Other concerns include potential harm from accidents with the robot, lack of reliability, incorrect or slow relaying of information to staff, lack of privacy, and navigation difficulties.

**Figure 1**

Examples of social robots: (*a*) iRobi (Yujin Robot); (*b*) Nao, a humanoid (Aldebaran); (*c*) Pepper, a humanoid (Softbank Corp.); (*d*) Paro, a pet-like robot (Intelligent System Co.); (*e*) Pleo, a pet-like robot (Innvo Labs); (*f*) Telenoid R1 (Osaka University and ATR Hiroshi Ishiguro Laboratory); (*g*) Philip K. Dick, an android (Hanson Robotics); (*h*) Hiroshi Ishiguro and his geminoid (ATR Hiroshi Ishiguro Laboratory).

## Robots for Children with Autism

**Teleoperated:** a robot that is operated remotely by a person, often over the Internet

Engineers and computer scientists are enthusiastic about the use of robots for children with autism spectrum disorder who have difficulty communicating with and understanding other people. The basic reasoning behind this is that robots are simpler to interact with than people are because robots are more predictable, have fewer states, and have a smaller range of actions. Therefore, children with autism may be able to learn about social cues from interactions with robots and then apply this knowledge to social interactions with people. Robots are being developed for several tasks: to elicit behaviors to diagnose autism and to increase prosocial behaviors; to model, teach, or practice skills; and to provide feedback or encouragement (Diehl et al. 2012). However, research to date has only been exploratory. Most studies have been done with a few individuals over only a few days with qualitative methods, no control groups, and limited diagnostic information on the participants. A range of different robots have been used, but these are often controlled by a therapist in the same room and are not autonomous (Scassellati et al. 2012). There have been mixed results with large variability between individuals (Diehl et al. 2012). Only some children show a preference for robots over other toys.

No conclusions can be made with such small sample sizes and methodological limitations. A further difficulty is showing whether children's interactions with robots can be transferred to improve functioning in other situations. One of the strongest clinical studies to date showed no differences in social behaviors (other than eye contact) when children interacted with a robot compared to when they interacted with a human on a collaborative task. Furthermore, the difference in eye contact may have been due to a novelty effect (Simut et al. 2016). Additional well-designed studies conducted in collaboration with clinicians are needed to show whether robot-assisted therapy provides benefits for some children, and psychologists will play an important role in this research.

## Telerobotics

Another area of robot development is teleoperation, in which mobile robots can be controlled by humans at a distance. In these cases, the robot is usually acting as a tool by which two humans can communicate with each other or a human can complete a remote task, rather than the robot being a social agent in itself. Several teleoperated robots exist, most of which look like a screen mounted at the top of a pole on a mobile base. However, some teleoperated robots have a more humanlike appearance (Kristoffersson et al. 2013). Teleoperated robots can be used in harsh environments such as space or the sea, for distant communication between people in business teleconferencing, or in telemedicine for specialist doctors to visit patients remotely in a hospital or at home. Technological hurdles, such as lack of network stability, inability to open doors or travel up and down stairs, and difficulties with navigation and docking, still exist for telepresence robots.

The use of telepresence robots has been shown to be beneficial in healthcare. For example, telepresence robots have been used by surgeons for postsurgical ward rounds and found to have similar patient satisfaction ratings as in-person visits (Ellison et al. 2007). Using the robot, doctors were able to make additional postsurgical visits to gastric bypass patients, resulting in significantly shorter hospital stays and cost savings (Gandsas et al. 2007). Similarly, the use of telepresence robots in intensive care allowed neurologists to respond more quickly to nurse pages and was associated with reduced length of patient stay as well as substantial cost savings (Vespa et al. 2007). Using telepresence robots rather than telephones allowed physicians quicker access to critical visual information (minutes rather than hours), enabling faster diagnosis and decision making.

Children with chronic illnesses, such as cancer, can become isolated from their friends due to missing school and being unable to join in with activities. In some cases, technologies can be used to facilitate communication (Liu et al. 2015). Sick children have used telepresence robots to attend school classes. Case studies indicate a mix of positive and negative interactions, but overall the robot can help provide a way to reduce social, emotional, and academic isolation for hospitalized children (Fels et al. 2001).

Minimally invasive robot-assisted surgery is another real-world application in which robots are operated remotely. The da Vinci surgical system is a leader in this field, with more than 500 units sold in 2013 across the United States, Japan, Europe, and other markets at a cost of US$1.5 million each, and revenue is projected to increase (Intuit. Surg. 2016). Despite promises of fewer complications and lower blood loss, a recent meta-analysis of 20 randomized controlled trials showed no differences between robot-assisted surgery and laparoscopic surgery in surgical blood loss, complication rates, or length of hospital stay (Broholm et al. 2016). The only difference was that robot-assisted surgery took longer. In comparison to open surgery, robot-assisted surgery took longer but also resulted in lower blood loss (Broholm et al. 2016). There is limited research on the perceptions and feelings of patients toward these robots.

**Humanoid:** a robot that has a body shape similar to a human, usually with a head, torso, arms, and legs

## Robot-Assisted Recovery from Stroke

Robot therapy following stroke has been shown to improve hand and arm function for patients in all stages of recovery (Basteris et al. 2014). Robots can also help with gait recovery, although whether robot therapy is better than other methods is not clear (Swinnen et al. 2014). Qualitative interviews reveal that patients think robot-assisted therapy has benefits for mobility, with the added convenience of being able to schedule exercises when they like. This increases independence and can improve mood. Indeed, some patients prefer the robot over a human assisting them with the exercises, despite technical and ergonomic difficulties (Cherry et al. 2016). The majority of these robots would not be classed as social because they are wearable and physically assistive and apply forces to the user's limbs. Feedback from patients with stroke consists of comments about how the system could be improved rather than any comments about their sociability (Hughes et al. 2011). However, small studies have investigated more socially assistive hands-off exercise robots for stroke rehabilitation. A closer match between the user's personality (extrovert or introvert) and the rehabilitation robot's behavior (nurturing or challenging exercise instructions) increased the time that people spent interacting with the robots (Tapus et al. 2008). This suggests that social aspects could be utilized to enhance adherence to the interactions of rehabilitation robots.

## Education

Robots have been used in education, predominantly in the areas of science and technology but also in foreign language teaching (Mubin et al. 2013). Robots can be used as a tool through which technical skills can be learned, can act as a peer by providing encouragement, or can function as teachers. Robotic kits are often used to engage students in learning about science and technology. Kit types include creative kits in which any kind of robots can be created (such as Lego), kits that come with wheels (e.g., cars) and are most suited to younger users, and kits that come as humanoids and are more suitable for older users (Basoeki et al. 2013). Preliminary evidence suggests that teaching children from low-income families using humanoid robots increases motivation, sense of community, and self-expression more than teaching children using creative-type kits (Han et al. 2015). Robots have also been tested for health education in pilot studies of children. A humanoid robot (Nao) was used in three sessions to administer quizzes either in a motivational way, using self-determination theory (with behaviors to increase competence, autonomy, and relatedness), or in a neutral way (Blanson et al. 2013). Diabetes knowledge increased over time and the children found it fun, especially in the initial sessions. The children mimicked the robot's interaction style, suggesting social modelling was occurring.

## Shopping Mall Guides

Robots are being used as guides in public places such as shopping malls and museums. Some of these robots are autonomous in usual use, but in research they are often operated remotely to gain better control over study conditions. Qualitative interviews with people in a Japanese shopping mall that had a guiding-type robot for over three years showed that people based their judgments mainly on the robot's appearance and the way it moved (Sabelli & Kanda 2015). They saw it as a mascot for the mall rather than a utility. Other interviews have shown that a shopping mall robot giving out instructions and flyers is seen by the majority of users to have benefits, including giving clear instructions and being enjoyable and good for children (Satake et al. 2015). Interestingly, 65% said they would prefer such services from a robot rather than a human, with comments indicating that the robot does not judge people based on appearance and treats everyone the same; some respondents also claimed that if the robot was too humanlike, then it would be scary. More than 90% wanted to use the robot again.

# CURRENT DIRECTIONS, CONCERNS, AND ETHICAL ISSUES

We will likely continue to see the development of social robots for these applications and others. Governments continue to be concerned about the rising proportion of people aged 65 and over and would like technological solutions to reduce healthcare costs. These governments see robots as useful both in industry and in homes. Europe, for example, has a strategic research agenda for robots, envisioning that they will impact every aspect of work and home, improving safety and service and creating jobs (euRobotics AISBL 2013).

Some researchers are concerned about the use of technology, especially by children. Turkle (2014) argues that we are developing an always-on culture in which children do not develop the capacity to enjoy solitude and devote time to self-reflection. Research suggests that our relationships with mobile devices may come at the cost of relationships with each other, with the presence of cell phones linked to feelings of decreased empathy and closeness during dyadic conversations (Misra et al. 2016). These kinds of concerns are also beginning to arise with robots.

There are concerns that robots are deceiving people about their real nature because robots can only simulate love or friendship. Some philosophers argue that this deception is unethical and may cause harm (Sparrow & Sparrow 2006). Sparrow & Sparrow believe that robots should only be used if cognitively aware people express a preference for robots over humans.

In fact, there is evidence that people do perceive robots to have advantages over humans in some aspects of healthcare; these advantages include increased perseverance, commitment, and availability, as well as decreased distraction from patients, in robots compared to human doctors (Broadbent et al. 2010). A survey of 420 people, including some parents and therapists of children with autism, showed that more than 80% agreed it was ethically acceptable to use robots with children with autism, although approximately half of the respondents did not want the robot to replace therapists and approximately 20% did not want the children to see robots as friends (Coeckelbergh et al. 2016).

Some work suggests that people like the social presence of robots, at least in healthcare. One study showed that 50% of hospital pain clinic patients did not mind the presence of a female humanlike robot in their first consultation with the doctor, 33% preferred the robot's presence, and only 6% preferred its absence (Yoshikawa et al. 2011). When the robot expressed empathy with the patient, this added to its positive effects. Smiling and nodding in synchrony with the patient during the consultation increased the number of patients who preferred the robot to be present to above 50% (Takano et al. 2008). When the robot smiled and nodded in synchrony with the doctor, patients' preference for its presence was 40%.

There are also concerns that, if robots are used as nannies to care for young infants, then infants may not develop linguistically, socially, or emotionally due to insufficient human care (Sharkey & Sharkey 2011). A code of ethics, in which safety, law, and social impact are important components, has been proposed for the use of robots (Lin et al. 2011).

It will be interesting to see how trust of robots develops in the future. A 2015 news article reported Samsung's warning that people should not talk about private matters in front of their smart TVs because the TV's voice recognition software could record and transmit conversations to third parties (BBC News 2015a). This news article also warned of home devices that knew when you were out; this information could possibly be relayed to others. Robots will have the ability to gather even more data about us, which may potentially be hackable or otherwise accessible and useful to others. Another recent news article reported that a talking doll that answers children's questions by looking up answers on the Internet (similar to Siri on the iPhone) could be hacked to say frightening things (BBC News 2015b). The hacking of our robots could potentially create many unsettling new threats.

**Android:** a robot with a human appearance (but not that of a specific individual)

**Geminoid:** a teleoperated robot that is built to resemble a specific human individual

**Wizard of Oz:** a situation in which people interact with a robot that they think is autonomous but that is secretly being operated by another person

**Telenoid:** a teleoperated robot designed to have minimal characteristics of a human, usually ageless and genderless with a head, torso, and short limbs

# WHAT MAKING ROBOTS CAN TEACH US ABOUT OURSELVES

## Creating Humanlike Robots

Some robots look humanlike; the androids built by Ishiguro & Nishio (2007) are examples. An android is a robot that is highly anthropomorphic in both appearance and behavior. Android science is an interdisciplinary field in which engineers build humanlike robots and cognitive scientists test these robots with humans to discover more about human nature. Using this feedback loop, Ishiguro's ultimate goal is to build androids that can take part in humanlike conversations (Ishiguro & Nishio 2007). Because that is currently impossible, he is building and studying geminoids. A geminoid is a robot built to look exactly like an existing person and teleoperated by a human in a so-called Wizard of Oz fashion. Through teleoperation, a robot can be made to act with the same behaviors, conversational abilities, and personality of a real person. A geminoid has, in effect, an artificial body and a human mind. A geminoid is intended to mirror a specific person; Ishiguro has a geminoid that is a likeness of himself (see **Figure 1**).

One robot, the telenoid, is a teleoperated robot with the minimal features of any human and has been built by Ishiguro and colleagues to possess the essence of humanness (**Figure 1**; Ogawa et al. 2011). It has a head, a face, short arms, and fused legs and is designed to have no gender or age. Its advantage is that it can be operated by anyone and the person interacting with it can perceive any number of variations of age, gender, and personality. The telenoid has received mixed reactions, including fear, from people interacting with it, and people prefer to talk to a real person than a teleoperated telenoid (Ogawa et al. 2011). However, a study of engineering students found that most operators of the robot reported that it could transmit their intentions to a moderate degree and most students interacting with the robot perceived its behavior as moderately sociable (Sorbello et al. 2014).

Even laypeople are beginning to build humanlike robots. One man with little knowledge of engineering or software successfully built a robot in his apartment that looked similar to movie star Scarlett Johansson (Bolton 2016).

Engineers are attempting to make robots look and behave identically to humans in part so that humans can interact with robots on a more intuitive and natural level. However, making robots behave like humans is difficult in many ways, not least due to limitations in technology preventing the production of a humanlike body that can perceive the world as we do and perform the same actions. Nevertheless, engineers are trying to make robots look and behave identically to humans.

Leaving aside the technical difficulties, there are many complex human behaviors that engineers must first define and then model. To illustrate the complexities of this task and to show that this effort to model human behavior can reveal more about ourselves, I examine two common social behaviors that roboticists are trying to model: social distance and gaze behavior.

The first example of human behavior that roboticists are attempting to model is proxemics, or physical and psychological distancing from others (Mumm & Mutlu 2011). Engineers argue that robots should show appropriate distancing behavior based on human norms to be better integrated into human society. Engineers have first turned to what psychologists and other social scientists have already discovered on this topic, which includes several theoretical models of dyadic interpersonal distancing. Whether approach from one partner results in reciprocal or compensatory distancing can depend on likability. Other factors influencing social distance include gender, culture, and age. When these models are tested in human–robot dyads, people respond to robots in social interactions in similar (although not exactly the same) ways as they respond to humans (Mumm & Mutlu 2011). This research can be applied to allow robots to approach people in socially acceptable ways when handing over objects. To create such behavior, researchers have systematically observed how humans approach each other and created robot models that try to use similar approach behaviors (Avrunin & Simmons 2014). Human participants preferred the approach behaviors of the robot when it used approach paths modelled on human behavior over purely straight-line paths but only when the robot approached people from behind. This illustrates the blending of research into human and robot behavior—first observing how we approach others, then programming the robot to behave the same way, and finally testing whether this modelled behavior in a robot is acceptable to people.

The second example of the attempt to create robots with humanlike appearance and behavior is the development of realistic eye models for robots and computer agents based on human eye appearance and gaze behavior (Ruhland et al. 2015). Human–robot interaction (HRI) researchers have studied head, eye, and body orientation as indicators of level of engagement in a social context (Srinivasan & Murphy 2011). This research has shown that social gaze functions to establish the robot as an agent, to communicate the robot's interest in a person, to signal conversational turn-taking, and to communicate which object the robot is referring to. A variety of different gaze acts, such as long gazes, short glances, gaze aversion, rapid gaze shifts, and eye scanning, as well as head movements, have been studied in robots to determine their effects in interactions with people.

For robots to be social agents, they must not only act in humanlike ways but also be able to perceive and understand human behavior. To create robots that can detect untrustworthy behavior in humans, engineers have studied the behaviors that elicit trust in human–human dyads during cooperative behavior games using both manual and automated coding systems (Lee et al. 2013). This research showed that face touching, arm crossing, leaning back, and hand touching were associated with less trustworthy behavior, and leaning forward, having the arms in the lap, and having an open-armed pose were associated with more trustworthy behavior. This work sheds light on our own tendencies and adds to Ekman's (1989) work on behaviors that indicate deception and lying and to work on emotional expression and trustworthiness (Boone & Buck 2003).

Because robots have limited language abilities, posture and gesture are important means by which robots can convey and detect emotions. Research suggests that people can interpret intended emotions from postural manipulations of robots (Beck et al. 2010). Roboticists have studied the biology of human body schema (self-awareness of body position in space) and applied this to robots, allowing robots to have an awareness of their own body positions (Hoffmann et al. 2010). It has been argued that this type of work can both help give robots new capabilities and also complement psychology and neuroscience research by creating and testing artificial models.

## Creating Pet-Like Robots

Pet-like robots, including Paro (a seal), Genibo (a dog), and Pleo (a dinosaur), have been developed for both therapy and play (**Figure 1**). Paro was developed as a therapeutic robot for people with dementia, as described in the section Healthcare Robots for Older People. Genibo was developed in Korea as a toy robot in the form of a bull terrier dog that can understand voice commands such as "sit," respond to patting, wag its tail, bark, and take photos. It is popular in Korea despite its cost. Pleo is a robot in the form of a baby dinosaur developed as a toy that can learn voice commands, sense special food that is held up to it, and react to touch. Pleo has been used with children to study relationships; however, research reveals children's interest is not sustained over time (Fernaeus et al. 2010). Other research includes the addition of a virtual version of Pleo to increase interactions and interest from children (Fernandez-Baena et al. 2015).

To increase the capacity of robots to provide companionship, several design principles have been incorporated into existing artificial pets. These include freedom for the robot to refuse an order, dependency of the robot on its owner to look after it and help it mature over time (to make the human feel responsible for it), juvenile traits in the robot to trigger emotional responses, and emotional exchanges (predominantly via nonverbal modes due to difficulties with speech comprehension) (Kaplan 2001). Pleo has been developed with this maturation concept in mind, as it learns to walk over the first few days with its owner.

To be successful, pet-like robots should display similar kinds of attachment behaviors to those displayed by real animals. Kaplan proposes that Ainsworth's strange situation test (which normally tests a child's attachment to his or her mother) could be used to test a robot's attachment to its owner (Ainsworth & Bell 1970, Kaplan 2001). If the robot displayed appropriate contact-seeking behavior, such as following its owner, and appropriate signaling behavior, such as blinking its lights or beeping toward its owner, then this would indicate to observers that the robot was attached to its owner. To achieve behaviors typical of attachment, the robot could be programmed with a motivational drive to stay with its owner. Like a pet dog, the robot would need to recognize its owner, monitor the presence of the owner during independent activity, and display short-term distress at the owner's absence and short-term happiness on the owner's return. Careful observations of dog behaviors in relation to their owners have shed light on how humans and dogs interact and provided a guide for the development of social robots (Faragó et al. 2014). Proxemics, orientation and gazing behavior, tail wagging, and greeting behavior were particularly important in dog response to owner activity.

# STUDYING HOW WE THINK, FEEL, AND BEHAVE TOWARD ROBOTS

The study of HRI is a fairly recent phenomenon. It is a cross-disciplinary field with its origins in the work of computer scientists and engineers as well as sociologists and psychologists. Because robots come in many shapes and sizes and have many applications, the field has a wide scope and researchers are still exploring its boundaries.

Research can be divided into what one could call simulated robot studies and real-world robot studies. Both types of study can contribute to knowledge of human–robot relationships. Simulated studies may employ written descriptions, photographs, or videos of robots instead of real robots or may use robots that aren't autonomous (a Wizard of Oz design). Simulated studies have the advantages of enabling a high degree of control over study manipulations, being quicker, and allowing robots to behave in more humanlike ways than they would normally be able to do. However, simulated designs have the disadvantage that people are under artificial conditions, and thus the results may not generalize to real robots and real-world conditions.

Real-world studies are typically conducted with actual robots in settings such as rest homes or shopping malls. In contrast to simulated studies, real-world robot studies are usually longer, harder to conduct, and much more expensive. They often involve collaborations between psychologists and engineers, and a robot must be built (or bought) and programmed to operate, preferably autonomously. This work is challenging in part because the technology is not as reliable or sophisticated as the researchers would like and because there are often no quick fixes for technological problems away from the laboratory. The robots also have limited capabilities and battery life.

There are advantages to real-world studies, however. First, people are actually interacting with robots, as opposed to watching videos of robots, reading descriptions of robots, or interacting with simulated robots. Second, real-world studies allow relationships to be formed and studied over a much longer period of time in natural environments. They can remove the artificiality of the lab and reduce response bias and novelty effects.

Over the past 50 years, observations of people's real-world behaviors toward technologies such as computers have led to the generation of hypotheses and theories about human behavior. In the next section, I examine several approaches and theories that are relevant to HRI, beginning with a historical perspective.

## A Visit to the Uncanny Valley

As early as the 1970s, a relationship was proposed between the humanlikeness of robots and feelings of comfort with them. A positive relationship was proposed, but it had a steep dip in comfort when robots looked almost but not perfectly human (Mori 1970, Mori et al. 2012). This dip is called the uncanny valley and explains feelings of discomfort and unease toward close-to-human robots. These feelings can occur when there is something fundamentally inhuman about a robot despite an otherwise close resemblance. For example, a robot may look humanlike but move in an odd manner or have a hand that is cold and lacks a bonelike structure within (Cabibihan et al. 2015). Mori's original theory likens the feeling of the uncanny valley to the way people feel about interacting with a dead body.

There are mixed findings concerning both the existence of the uncanny valley and its explanations (MacDorman & Chattopadhyay 2016). Some of the variability between studies may be due to differences in the terms used to measure these feelings—including familiarity, comfort, threat, likability, similarity, unease, uncanniness, and eeriness. This is partly because the original paper was in Japanese and there is no direct translation into English. The variation in the types of robot used has also created differences between studies. Robots can vary in many aspects of appearance; furthermore, sometimes only the face is used, whereas other times the whole body is shown.

Some evidence supports the existence of the uncanny valley, with a demonstrated drop in familiarity and a rise in eeriness in the middle of a series of images morphed from a robot face to a human (MacDorman & Ishiguro 2006). However, other work has found people like realistic humanlike robots and found no evidence for a dip in feelings of comfort in the middle of a continuum of faces morphed from cartoonlike to realistic (Hanson et al. 2005). Similarly, there was no evidence for a dip in familiarity or rise in eeriness when a range of robots that varied in humanlikeness were shown in videos (MacDorman 2006).

Factors other than humanlikeness may contribute to robots falling into the uncanny valley. Robots rated equal on humanlikeness were rated differently in strangeness or familiarity, suggesting other variables contribute to these perceptions (MacDorman 2006). Other work supports this conclusion, with a range of design features such as height, bulk, and bipedal form adding to or subtracting from humanlikeness and contributing to the perceived threat or likability of robots (Rosenthal-von der Pütten & Krämer 2014). A study of what makes people appear creepy also found that multiple factors of appearance and behavior contributed to feelings of threat, including unkempt hair, odd dress, and unpredictable behavior (McAndrew & Koehnke 2016). Certain occupations were rated as creepier than others, including clowns, who have distorted human appearance, and taxidermists and funeral directors, who are associated with death.

In terms of theory, ratings of unease toward not-quite-humanlike robots may be explained by evolutionary theory because it could be beneficial to feel revulsion as a defense mechanism to protect against infection from diseased or deceased bodies. Unease toward robots could alternatively be caused by category uncertainty (i.e., wondering whether it is human or not). A similar theory, realism inconsistency, claims that human and nonhuman features are combined in a robot, creating an uncanny effect. Supporting this theory, one study found that a mixture of real and artificial features (e.g., eyes, eyelashes, mouth) in the same face created eeriness to a greater extent than a slow morphing from real to computer animated across all facial features together (MacDorman & Chattopadhyay 2016). Furthermore, a humanlike face with silver skin and empty-looking eyes was rated more eerie than the same face with humanlike skin and eyes (Broadbent et al. 2013). The eyes appear to be particularly important when judging whether a face is alive or not (Looser & Wheatley 2010). Together, this work suggests that conflicting cues are an important component in uncanniness as they may violate our expectations of humans.

The violation of perceptual expectations may occur when a robot looks like but does not act like a human. Video clips of an android (human appearance and mechanical action), a human (human appearance and human action), and a more mechanical robot (mechanical appearance and mechanical action) performing actions were shown to 20 people in a fMRI machine (Saygin et al. 2012). The results suggested greater brain activity in the bilateral anterior intraparietal sulcus (an important part of the action perception system) when viewing the android than when viewing the human and the mechanical robot. This provides support for the predictive coding framework of neural processing, in which brain activity is higher when observed behavior is mismatched with expectations. That is, people expect a human to walk in a humanlike way, so if the android that looks humanlike walks in a mechanical way it violates our expectations, resulting in large feedback error signals in the brain (MacDorman & Chattopadhyay 2016). The study by Saygin and colleagues (2012) also illustrates that robots can be used to study human perceptions of movement.

## Robots Change, Challenge, and Reveal Us: The Second Self

In the 1980s, Sherry Turkle studied human–computer relationships from a psychoanalytic perspective and described the insights people gain about themselves through the use of computers. She wrote that the cultural phenomenon that occurred in the early 1980s, in which people likened human experiences, such as memory, to computer processes, allowed a simplified understanding of ourselves (Turkle 2005). Programming computers also fostered a sense of control over the world and could be a form of self-expression in which what you created in programs reflected your personality. Turkle (2005) wrote that the early days of computing taught children about logical thinking and procedures, whereas children now use more sophisticated modern computers on a surface level, and their understanding of how they actually work has been lost. From this perspective, the engineers and scientists who are programming the brains and behaviors of robots are learning more about models of thought processes and behavior than are the people who are interacting with robots on a surface level.

Robots may challenge us by prompting us to become more reflective about ourselves. Turkle (2005) describes the computer as an evocative object that makes us question how we think and what makes up our nature. Similarly, robots prompt questions about what it is to be human and how we differ from robots (Turkle et al. 2006). In addition, Turkle and colleagues (2006) comment that in-depth observations of the different ways children and older adults treat robots can reflect their family situation and that people may project their psychological needs in their interactions with robots. Watching children's interactions with robots can therefore be useful in gaining insights into their personal situations and experiences.

## We Mindlessly Apply Social Rules to Robots: The Media Equation

Another pioneering researcher on HRI was Clifford Nass, a computer scientist and sociologist. His seminal work on the media equation informed much of the field of HRI as it is today (Nass & Reeves 1996). Nass & Moon (2000) demonstrated in a series of studies that people treat computers and other technologies as if they were human even though they know this is not the case. This is somewhat irrational, and Nass and colleagues argued that people mindlessly apply social rules to computers. The evidence for this comes from several angles.

First, there is evidence that people use stereotypical social categories, such as gender, ethnicity, and in-group and out-group status, when interacting with computers. For example, just as women are assumed to have more caring competencies and men to have more agentic competencies (Huddy & Terkildsen 1993), computers with a female voice were rated more informative about love and relationships, whereas computers with a male voice were rated more knowledgeable about computers, despite the computers giving identical information (Nass et al. 1997). Similar to findings on racial prejudice (Brown 1995), one study found that people rated computer agents with a face of the same ethnicity as them to be more attractive, trustworthy, persuasive, and intelligent than agents of another ethnicity (Nass & Moon 2000). Moreover, similar to findings on in-group bias exhibited by people toward others (Fu et al. 2012), studies have found that participants with an armband the same color as the computer's screen band rated the computer more highly and conformed to its instructions more than they did if the bands were a different color (Nass et al. 1996, Nass & Reeves 1996).

Second, experiments show that people use overlearned social behaviors, such as politeness, in their interactions with computers. For example, after using a computer, people evaluate its performance more highly if the same computer delivers the rating scale than if another computer delivers the scale or if they rate it with pen and paper (Nass et al. 1999). This result is similar to experimenter bias, in which people try not to offend a human researcher. Another example of a social behavior is reciprocity—we help others who help us. People helped a computer with a task for more time and more accurately if the computer first helped them with a task than if it did not (Fogg & Nass 1997). Reciprocal self-disclosure is also evident in the way people respond to computers. People's responses are more intimate to computers that disclose more about themselves in the initial interaction than to other computers (Moon 2000).

Similar studies have shown that people mindlessly apply social rules to robots as well. In terms of racial prejudice, German participants rated a robot that had a German name and was described as having been developed in Germany as warmer and as having a better design and a greater capacity to experience the world than an identical robot that had been given a Turkish name and was described as having been developed in Turkey (Eyssel & Kuchenbrandt 2012). The participants also reported feeling closer to the German robot. In terms of gender stereotypes, a robot with short hair and flat lips was rated less feminine and more suitable for typically male tasks (e.g., technical work) than an otherwise-identical robot with long hair and shapely lips, which was rated more feminine and more suitable for typically female tasks (e.g., child rearing) (Eyssel & Hegel 2012). Robot gender has been shown to influence participants' behavior as well. For example, people in a museum were more likely to donate money to a robot research lab when the robot asked with a female voice than when it asked with a male voice (Siegel et al. 2009).

Just as people can be polite to computers, people can be polite to robots. In interactions with Nao, some people were polite and tried to help the robot; others, however, called the robot names and enjoyed having power over the robot (Rehm & Krogsager 2013). Similarly, approximately 50% of people greeted a robot receptionist at a university campus in some way (e.g., by typing hello) before the rest of the interaction, and the presence of a greeting predicted a more sociable and polite subsequent conversation with the robot (Lee et al. 2010).

Some research shows that people demonstrate reciprocity toward robots. For example, people's perceptions of a care robot were more positive if the robot asked for help and returned the help with a favor than if the robot did neither of these things (Lammer et al. 2014). In the prisoner's dilemma game, two criminals are faced with a situation in which cooperative behavior (mutual silence) results in a lower prison sentence for both, but betrayal results in the betrayer being set free and a longer prison term for the betrayed. In a repeated version of this game, reciprocal behavior is often employed. In one study, participants demonstrated the same amount of reciprocal behavior toward a robot opponent as they did toward a human opponent (Sandoval et al. 2016). Furthermore, the amount of reciprocity shown toward the robot was higher when the robot showed cooperative behavior in the first round than when it displayed random behavior in the first round.

However, there is evidence that not all reactions to robots are mindless and that there is variation in the degree to which people display social behavior toward robots. One study looking at verbal responses to a talking wheelchair robot suggested that people were not reacting mindlessly to the robot; rather, reactions differed according to people's goals and people were aware of their choices of how to respond (Fischer 2011).

A common approach in HRI research is to recreate experiments from psychology, repeating what the experimenters originally did to test participants' reactions to humans but observing reactions to robots instead. These studies aim to determine whether we behave toward robots in the same ways as we behave toward humans. One such study was based on Milgram's obedience paradigm (Milgram 1963). In this case, rather than asking participants to give increasing levels of electric shock to a human actor, participants were asked to give electric shocks to a robot (Bartneck et al. 2005). The results showed that 100% of the participants shocked the robot to the maximum level, despite the robot's protests and requests to stop the experiment, compared to 65% of the participants in Milgram's original work who shocked the human actor to the maximum level. This suggests that people treat robots differently to humans in some circumstances, perhaps in this case because they did not think the robot could feel pain.

Studies on honesty provide another example of this kind of replication. Research in psychology has shown that the presence of an observer can increase people's honesty, but incentives for cheating can reduce honesty (Covey et al. 1989). In a robot version of this work, participants given incentives to cheat were shown to be less honest when alone compared to when they were accompanied either by a human or by a simple robot (Hoffman et al. 2015). This illustrates that the social presence of robots may make people feel as though they are being watched and increase their honesty in an effect similar to that produced by the presence of humans.

## We Perceive the World Through a Human Filter: Anthropomorphism

Anthropomorphism refers to our tendency to see humanlike characteristics, emotions, and motivations in nonhuman entities such as animals, gods, and objects (Epley et al. 2007). Anthropomorphism can be conceptualized and measured in different ways—from a simple rating of humanlikeness on a single-dimension scale to broader and less concrete conceptualizations including mind, emotionality, intention, consciousness, and free will (Waytz et al. 2014).

The tendency of humans to anthropomorphize objects can be explained by the fact that being human is the thing we know best. When trying to understand or interact with an unfamiliar nonhuman agent, people use their knowledge of themselves as a basis for understanding these entities. In other words, being human forms our frame of reference. Our biology is thought to contribute to this tendency, as watching a nonhuman agent perform a humanlike behavior may activate mirror neurons and therefore cause us to experience a similar state (Epley et al. 2007).

Neurophysiological research suggests that we react more to a nonanthropomorphic robot when a human acts socially toward it (Hoenen et al. 2016). In this study, watching a robot vacuum cleaner being verbally harassed triggered more compassion and a greater response in the mirror neuron system than a situation in which the robot was not harassed (Hoenen et al. 2016). The authors interpret this research as showing that observing someone interact socially with a robot can increase perceptions of the robot's social agency.

Our tendency to anthropomorphize increases with the humanlikeness of a nonhuman entity. This may be because the entity is seen as more similar to the self. For example, robots that have a greater number of facial features (nose, mouth, eyes, etc.) are perceived as more humanlike than those with fewer facial features (DiSalvo et al. 2002). Epley et al. (2007) hypothesize that lack of certainty about a nonhuman entity will increase the tendency to anthropomorphize. Experimental work supports this hypothesis by showing that agents described as less predictable are anthropomorphized to a greater extent (Waytz et al. 2010).

Epley and colleagues (2007) also propose that people have an inherent need to be social and that when they are lacking social ties, anthropomorphism of nonhuman entities will help meet this need. This hypothesis was supported by research showing that lonely people had a greater tendency to anthropomorphize a humanlike robot than nonlonely people (Eyssel & Reich 2013). These experiments demonstrate that robots can serve as a way to study the human tendency to anthropomorphize nonhuman objects, as well as to inform us about how we perceive robots.

## We Perceive Mind in Robots: Mind Perception

The question of whether robots can think has interested humans since the early days of computing. Alan Turing's (1950) famous imitation game or Turing test reasons that if an interrogator asking questions of a human and a computer is unable to distinguish which is which, then one would have to conclude that the computer was intelligent. Accordingly, the answer to the question of whether robots can think depends on how advanced the technology is and the opinion of the person asking the question.

The question of whether people think that robots can think is different. Perceived mind has been found to consist of two dimensions of mind—the capacity for agency (e.g., self-control, morality, memory, emotion recognition, planning, communication, and thought) and the capacity for experience (e.g., hunger, fear, pain, pleasure, rage, desire, personality, consciousness, pride, embarrassment, and joy) (Gray et al. 2007). In this study, people ascribed different amounts of agency and experience to different kinds of beings: An adult human was perceived as having the most agency and experience, a baby was perceived to have high experience but no agency, and God was perceived to have high agency but no experience. In this way, perceived mind can differ from perceived humanness. No one would argue that a baby is not human, but everyone agrees its mind is not yet fully developed. The robot in Gray et al.'s (2007) study was perceived to have little ability to experience but to have a moderate degree of agency. This suggests that robots are seen by most people to have at least some components of mind.

Different kinds of robots are likely to be perceived as having more or less mind. For example, people who see a video of a robot's head from the front, with a face in view, think the robot has more mind on the experience dimension than people who see the robot's head from behind, with wires in view (Gray & Wegner 2012). Subsequent work on interactions with actual robots has shown that people perceive a robot with a face on its screen as being more humanlike and having both more agency and more experience than a robot with no face at all (Broadbent et al. 2013).

Morality has been linked to perceptions of mind. It has been argued that moral judgments require a dyad in which intention is perceived on the part of an agent and the experience of suffering is perceived on the part of a patient (Gray et al. 2012). Because robots are perceived to have aspects of mind, this begs the question of whether robots should behave morally and be treated morally. In one experiment, children had a social interaction with a Robovie robot (talking, playing, and hugging); the experimenter then interrupted to put the robot in a closet while the robot protested that it was not fair, that it was afraid of the dark, and that it did not want to go in the closet. The majority of the children saw the robot as having thoughts and emotions and as a social agent. All of the children thought it was all right to put a broom in the closet, whereas less than half of the children thought that it was all right to put the robot in the closet and all of them thought it wrong to put a human in the closet (Kahn et al. 2012a). This is in accordance with previous research showing that robots are perceived to have less mind than humans. In another study with undergraduate students, Robovie was programmed to make a mistake in a game; on average, participants rated it only slightly accountable and significantly less accountable than they said they would rate a human for the same mistake (Kahn et al. 2012b).

Research on ethical dilemmas suggests that we think it less wrong for robots to make logical decisions that sacrifice one for the many than for humans to make the same decisions, supporting earlier findings that we attribute different standards to humans and robots (Malle et al. 2015). Furthermore, this suggests perceptions that robots are less capable of feeling emotions than humans but that they have some capacity for cognition. Although the morality of robots is a somewhat philosophical topic, it does have real-world implications for a future in which robots in the real world cause accidents. Who is to blame? The robot? The developer? The owner?

## Emotional Attachment to Robots

Studies attempting to assess people's emotional attachment to robots have observed some forms of attachment. Emotional attachment, as measured by positive interactions, perceptions of the robot as having mind, and positive reactions to the robot as a companion, was demonstrated in children interacting with Aibo, a robotic dog designed for companionship, over a short interaction period (Weiss et al. 2009). Evidence suggests that almost all children attribute biology, mental life, sociability, and moral standing to real dogs and fewer, but still the majority, attribute these characteristics to stuffed toy dogs and robotic dogs (Melson et al. 2009). At least 75% of children thought the robotic dog could be their friend. In observations, preschoolers explored the robotic dog more than a soft toy, attempted to interact with it more, and showed greater apprehension towards it, whereas children aged 7–12 showed five times as much affection (through patting, hugging, etc.) for a real dog than for the robotic one. Analysis of themes within online chat forums about Aibo found that owners wrote about the robot having batteries and being an object but also seeming alive and having emotions and personality; owners also described forming an emotional attachment with Aibo (Friedman et al. 2003).

Several studies of robots have explored whether people feel situational empathy for robots when they are harmed. For example, watching a robot expressing fear of losing its memory and then observing it lose its memory induced more empathy than a control condition in which memory was not lost (Seo et al. 2015). Other work using fMRI suggests that people experience similar but weaker late top-down processing of empathy in response to pictures of a robot's finger being cut compared to pictures of a human's finger being cut (Suzuki et al. 2015). Giving more background information about a small bug-like robot increased participants' hesitation to hit it with a mallet (Darling et al. 2015), suggesting empathy was increased when they knew more about the robotic life form.

The display of positive behavior may increase affection toward robots. For example, a robot that expressed encouraging comments was rated higher on a measure of friendship than a robot that expressed more neutral comments (Pereira et al. 2011).

## Robots Versus Other Technologies: Physical Embodiment

One interesting question is whether we form different relationships with robots, virtual robot characters (presented as avatars on a screen), and computers. Preliminary evidence suggests that we do. People rated a physical robot that was in the room with them as more watchful and enjoyable than both a simulated robot on a computer and a real robot shown through teleconferencing (Wainer et al. 2006). In another study, children were asked to administer electric shocks to either a physically present robot or a simulated robot on a computer screen, both of whom displayed colored bruises to indicate pain after being shocked; the children were then asked how much they empathized with the robot. Children empathized significantly more with the embodied robot than the computer-simulated robot (Kwak et al. 2013).

People tend to form a closer therapeutic alliance with robots than with computers and to be more compliant with the instructions of robots. In one study, people interacted for a longer time with a diet coach robot than either a diet coach computer or a pen-and-paper diet diary and also rated their alliance with the robot more highly (Kidd & Breazeal 2008). In subsequent work, people were shown to be more likely to follow relaxation instructions from a robot than from a computer tablet with the same software and voice (Mann et al. 2015). People spoke and smiled more at the robot than at the computer and trusted the robot and enjoyed interacting with it more. Their desire to interact with the robot again was higher than their desire to interact with the computer tablet again.

Trust is critical to successful interactions with robots. The concerns people currently have over security and privacy on digital devices (Chin et al. 2012) are likely to transfer to robots. A recent review showed that robot performance factors, such as reliability and failure rate, had large effects on people's trust. Robot attributes, such as personality and anthropomorphism, still had significant but smaller effects on trust (Hancock et al. 2011).

Physical embodiment may result in different physiological reactions to robots than to more machinelike entities. For example, reactions were greater when people were asked to a touch a robot on the eye or on the buttocks than when asked to touch it on the arm (Li et al. 2016). Physiological effects can also be seen in reactions to healthcare robots, with research showing that stroking Paro can reduce blood pressure and heart rate in rest-home and hospital residents (Robinson et al. 2015).

## Robot Abuse

The rights of robots themselves and the potential for them to be abused should not be ignored. Studies in shopping malls have shown that children are well behaved toward robots when they are with their parents. However, without adults, groups of children can congregate and abuse the robot—blocking its path, calling it names, kicking it, punching it, ignoring its polite requests for them to stop, and stopping only when they become bored or when parents intervene (Brscić et al. 2015). To reduce robot abuse, the authors demonstrated that the robot's best strategies were avoidance and escape, because attempts by the robot to change verbal behavior or gently push to continue on its way unobstructed were both found to be ineffective.

This finding is not unique; similar bullying behavior by groups of young people has been observed toward an information-type robot in a plaza area (Salvini et al. 2010). Again the robot was not abused when researchers accompanied the robot, only when people thought the robot was alone. Observations of people interacting either alone or in pairs with a small wheeled robot showed that boys aged from seven to the early teens were the most aggressive, sometimes trapping it, covering its eyes, or verbally abusing it (Scheeff et al. 2002). If the robot responded with a fearful or sad facial expression, then the abuse increased, whereas if the robot responded with an angry expression and drove at the boys, then better treatment ensued.

One might reasonably argue that we should not worry about robot abuse if robots cannot suffer in the same way that humans do. However, Whitby (2008) argues that because robots might look humanlike, behave in humanlike ways, and take the role of humans, they are more than just objects. He suggests that we must make some agreement regarding how robots should be treated and how they can be designed to look and behave in order to reduce the risk of maltreatment. Additionally, studying the abuse of robots may allow us to gain insights into human behavior and ways to mitigate the abuse of humans and animals.

## CONCLUSIONS AND FUTURE DIRECTIONS

This review has demonstrated that social robots are starting to become more common in our society and can benefit us by providing companionship, increasing communication, and reducing costs, especially in healthcare settings. Engineers are attempting to make robots look and behave like humans and animals so that we feel more comfortable with them. However, robots can also make us feel uncomfortable, especially when their appearance is inconsistently humanlike and thus threatening or when their behavior violates expectations. Interacting with robots can make us question who we are, and we can project our desires onto them. Theories suggest we are wired through a combination of nature and nurture to perceive robots through human filters. We mindlessly interact with robots and other technologies as if they were human and we perceive humanlike characteristics in them, including thoughts and emotions. However, we do not see them as having as much mind as humans do, nor do we ascribe to them the same moral rights and responsibilities as humans. We can experience empathy for and attachment to robot pets but to a lesser degree than live pets. In addition, we feel closer to actual robots than virtual robots or computers, suggesting that physical embodiment is important in our relationships with artificial technologies.

What does this mean for the future? David Levy (2007) argues in his book *Love and Sex with Robots* that people (men in particular) often have few close friends yet crave affection. He argues that people may prefer relationships with robots that are programmed to always be social, smart, and loyal over relationships with unpredictable humans who do not always behave as desired and get upset when we behave badly. Ethicists even argue that the creation of such beings may lead to the breakdown of society because people will prefer to interact with robots rather than each other (Whitby 2008). In some ways, this aligns with Turkle's (2005) comments that the first visitors to Disney's Animal Kingdom were disappointed that the real animals were not as realistic as their animatronic versions at Disney World and had less lifelike behavior. In her work, Turkle (2010) questions the advantages that real animals have over simulated ones and outlines the child's perspective that simulated animals can be better in some situations. She suggests that our relationships with robots make us question the purpose of life itself.

A biddable designer human with none of the bad features of real humans and all of the good features is a tempting promise. But is it possible? It would require an incredible feat of engineering and is not possible with today's technology—battery power, materials, language comprehension, actuators, sensors, etc.—let alone the gaps in our understanding of the human cognition, emotion, and behavior on which the robot needs to be modelled. If we could create superior versions of humans, how would we feel toward these beings? With this question, we come full circle back to the arena of science fiction movies, in which humans and robots live together in strange, tension-filled dramas or in which humans are fighting for their lives.

This discussion opens up the question of what we want to achieve and why. Why are we going beyond building useful robots that can help in difficult environments? We have found that companion robots can provide benefits in contexts in which people have restricted opportunities to socially interact with human companions, animals, or doctors, but how far do we want to go in terms of humanlikeness? Are we building robots because we want to build a perfect human? Yet how can a robot be a perfect human when it is not even human? What is humanness?

Humans have a fundamental tendency to create, and the ultimate creation is another human. Engineers know that they need to understand more about human beings to make humanlike robots, and they are looking to psychology for several reasons: Psychology can help engineers understand and model humans better, perform experiments with appropriate methods, and develop therapeutic robots.

Although the field of HRI is still dominated by engineers and computer scientists, psychologists are beginning to become involved, and the field has rapidly expanded in the past few years. Most research has focused on the technical side of robotics, and more research is needed on the ways humans respond to and work with robots. The research is still in its exploratory phase, and the rapid expansion feels a bit like a runaway train. There is enormous potential for psychologists to contribute to this strangely compelling field. This can be a win-win situation, with the study of human behavior informing the construction of robots and tests with robots informing us about human cognition, emotion, and behavior. What will be the consequences of the human quest to make copies of ourselves? Psychologists have a role to play in helping shape our future and that of our robot companions.

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