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ORIGINAL ARTICLE

Can Robots Manifest Personality?: An Empirical Test of Personality Recognition, Social Responses, and Social Presence in Human–Robot Interaction

Kwan Min Lee[1], Wei Peng[2], Seung-A Jin[1] & Chang Yan[1]

1 Annenberg School for Communication, University of Southern California, Los Angeles, CA 90089
2 Department of Telecommunication, Information Studies & Media, Michigan State University, East Lansing, MI 48824

Personality is an essential feature for creating socially interactive robots. Studies on this dimension will facilitate enhanced human–robot interaction (HRI). Using AIBO, a social robotic pet developed by Sony, we examined the issue of personality in HRI. In this gender-balanced 2 (AIBO personality: introvert vs. extrovert) by 2 (participant personality: introvert vs. extrovert) between-subject experiment (N = 48), we found that participants could accurately recognize a robot's personality based on its verbal and nonverbal behaviors. In addition, various complementarity attraction effects were found in HRI. Participants enjoyed interacting with a robot more when the robot's personality was complementary to their own personalities than when the robot's personality was similar to their own personalities. The same complementarity attraction effect was found in participants' evaluation of the robot's intelligence and social attraction. Participants' feelings of social presence during the interaction were a significant mediator for the complementarity attraction effects observed. Practical and theoretical implications of the current study for the design of social robots and the study of HRI were discussed.

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After years of development, robots are no longer mere technological supplementary tools for labor-intensive or hazardous tasks (e.g., factory automation, military operation, and even space or seabed exploration). Robots are now becoming a part of our daily lives. They are increasingly being designed to serve as pets, nurses, office assistants, tour guides, teachers, domestic servants, and even emotional companions (e.g., Sony AIBO and QRIO, Samsung April, MIT Kismet, Carnegie Mellon Vikia, Honda ASIMO). These robots are called socially interactive robots (Fong,

Corresponding author: Kwan Min Lee; e-mail: kwanminl@usc.edu.

Nourbakhsh, & Dautenhahn, 2003) or simply social robots (Breazeal, 2003) because they can autonomously interact with humans in a socially meaningful way.

In order for these social robots to function well in the above-mentioned roles, a plethora of literature has suggested that it is critical for them to have intimate and effective social interaction with humans (Breazeal, 2003; Duffy, 2003; Fong et al., 2003; Severinson-Eklundh, Green, & Huttenrauch, 2003). But how can these robots achieve satisfactory social interaction with humans? The following "social" characteristics are suggested to be critical for robots to become socially interactive: "recognize other's emotions and/or express their own emotions," "communicate with high-level dialogue," "learn/recognize models of other agents," "establish/maintain social relationships," "use natural cues (gaze, gesture, etc.)," "may learn/develop social competencies," and "exhibit distinctive personality and character" (Fong et al., 2003, p. 145).

Among the seven characteristics suggested above, the current study focuses on the personality element for the following three reasons. First, in contrast to a number of studies on other characteristics of social robots, such as emotion, dialogue, gesture, and learning ability, very few studies on the personality of social robots exist (Miwa, Takanishi, & Takanobu, 2001). Second, these existing studies on robot personality are limited in that they are based on the assumption that robots are tools to be used rather than social companions to interact with (see Severinson-Eklundh et al., 2003). Finally and most importantly, we believe that personality is a key element for creating socially interactive robots and that studies on this dimension will facilitate enhanced human–robot interaction (HRI). This is because the personality of a robot can provide users with better affordance, which makes it intuitive and natural for the users to understand the robot's behaviors (Hara & Kobayashi, 1995; Norman, 1990).

Personality "represents those characteristics of the person that account for consistent patterns of feeling, thinking, and behaving" (Pervin & John, 1997, p. 4). Although the concept of personality has been conceptualized in countless different ways, one of the most acknowledged conceptualizations is to cluster the number of personality traits into the "Big Five Factors" (John & Srivastava, 1999). The Big Five Factors classifies human personality into five dimensions: extroversion, agreeableness, conscientiousness, neuroticism, and intellect.

Of the five dimensions, the current study focuses on the extroversion dimension for the following three reasons. First, along with the agreeableness dimension, the extroversion dimension is a particularly important factor for interpersonal interaction. Consequently, this dimension will be critical for HRI too. Second, a considerable amount of research indicates that extroversion is the most accurately observable dimension among the Big Five Factors (Lippa & Dietz, 2000). Finally, this dimension has been proven to be important in human–computer interaction (HCI) (Isbister & Nass, 2000; Moon & Nass, 1996; Nass & Lee, 2001), and it is reasonable to assume that it will continue to be important in HRI.

The extroversion/introversion of a person is inferred by various cues, such as physical appearance, occupation, economic status, language, and gestures (Ekman, Friesen, O'Sullivan, & Scherer, 1980). Among them, verbal (e.g., voice, language, pitch, speech rate) and nonverbal (e.g., gestures, body movement, facial expression) cues are found to be most reliable and prominent for the judgment of personality (Pittam, 1994; Riggio & Friedman, 1986; see the Manipulation section for a detailed discussion of specific verbal and nonverbal parameters found to be related to the judgment of extroversion/introversion). Consequently, the current study manipulates both verbal and nonverbal cues of a robot, and tests how people respond to the robot manifesting extroversion/introversion through its verbal and nonverbal cues.

Theories predicting human responses to robots with personalities

The current study investigates four research issues with regard to human responses to robots with personalities: (a) recognition of a robot's personality, (b) application of a personality-based social rule to a robot manifesting personality, (c) mediating effects of a robot's social presence on social responses, and (e) individual differences in social responses to a robot. Based on theories in communication and social psychology, we set four hypotheses and one research question (RQ) related to the above-mentioned issues.

The media equation theory: will people equate social robots with real social actors?

The term "media equation" means that "individuals' interactions with computers, TV, and new media are fundamentally social and natural, just like interaction in real life" (Reeves & Nass, 1996, p. 5). The main reason is that human brains had evolved in a world in which all perceived objects were real and only humans possessed human-like shapes and human-like characteristics such as language, rapid interaction, emotion, personality, and so on. Therefore, to human minds, anything that seemed to be real was real and any object that seemed to possess human characteristics such as language was a real human. When people use simulation technologies such as media and computers, people usually do not overcome the evolutionary limitation of accepting everything at its face value and respond to simulations of things and humans as if they were real, and thus, the media equation occurs.

Focusing on human responses to computers, Clifford Nass and associates have built the research paradigm of "Computers Are Social Actors (CASA)" and have discovered that individuals automatically apply social rules in their interaction with computers as if they were interacting with real human beings. This research paradigm is based on the idea that when confronted with a machine having anthropomorphic cues that are related to fundamental human characteristics, (a) individuals automatically respond to the machine socially, (b) are swayed by the fake human characteristics of the machine, and (c) do not process the factual information that the machine is not a human.

Primary cues that appear to be important are words for output, interactivity, filling of roles traditionally held by humans, human-like characteristics (e.g., face, voice, ethnicity, gender, and personality) (Nass & Moon, 2000). It is argued that these kinds of cues *automatically* (Langer, 1989; Nass & Moon) invoke schemata associated with human–human interaction, without the need to psychologically construct a relevant human (see Nass & Moon, 2000, for a full review).

Under the CASA research paradigm (Nass & Moon, 2000; Reeves & Nass, 1996), Nass and colleagues have discovered that individuals not only recognize the personality of a computer but also apply a personality-based social rule (e.g., similarity attraction, complementarity attraction) to the computer after they recognize its personality (Isbister & Nass, 2000; Nass & Lee, 2001). The recognition of the personality of a computer can be called the "first-degree social response" because it is the process of classification and identification of the fundamental social characteristics. Subtle and complicated attitudinal and behavioral changes to a computer after the recognition of its personality can be referred to as the "second-degree social response" because it is an advanced social response, which is based on and triggered by the first-degree social response. For example, recognizing personality cues of both linguistic and paralinguistic parameters of a computer-synthesized speech is the first-degree social response, and applying the consistency attraction rule to the speech after the recognition—that is, favoring a synthesized speech whose verbal and nonverbal cues manifest consistent personalities—is the second-degree social response (Nass & Lee, 2001).

The second-degree social response is much more complex and critical than the first in that it may not happen even when people clearly show the first-degree social response. That is, although the first-degree social response can be applied to various objects due to the lack of describing terms (e.g., this car is very extrovert) or from personal affection after years of use (e.g., this pen has been very faithful to me), the second-degree social response will be applied only to an object that manifests true social characteristics. Therefore, the test for the second-degree social response to an object can be regarded as a "Turing Test" (Turing, 1981) for the social characteristics of the object.

Thanks to various anthropomorphic features and advanced technologies (e.g., autonomous movement, anthropomorphic shapes, advanced artificial intelligence [AI], speech recognition, and generation), robots are likely to be perceived as more human than computers. Therefore, we hypothesize that both the first- and the second-degree social responses observed in HCI will also be discovered in HRI.

H1: People will recognize the personality of a robot when the robot manifests a personality through its verbal and nonverbal cues.

H2: People will apply a personality-based social rule to a robot when the robot manifests a personality through its verbal and nonverbal cues.

Theories of attraction: what personality-based social rules will people apply to social robots?

With regard to H2, no particular personality-based social rule is specified in the current study because there are two equally compelling personality-based social rules in interpersonal interaction and HCI literatures—*similarity* attraction versus *complementarity* attraction.

The similarity attraction rule holds that people seek out others who are similar to themselves, and prefer to interact with similar people. According to this rule, perceived similarity, which is the degree to which we believe another's characteristics—including but not limited to demographics, ethnicity, political attitudes, and personality—are similar to ours, is often sufficient to attract us to others (Infante, Rancer, & Womack, 1997). This rule has been confirmed by numerous studies in psychology and communication (Blankenship, Hnat, Hess, & Brown, 1984; Byrne & Griffit, 1969; Griffit, 1966; Nass & Lee, 2001) with the context ranging from communication skill matching (Burleson & Samter, 1996) to personality matching in long-term romantic relationships (Richard, Wakefield, & Lewak, 1990).

The complementarity attraction rule, on the contrary, holds that people are more likely to be attracted to those whose personality characteristics are complementary to their own, so that their own personalities—especially the dominance/submissiveness dimension—can be balanced (Isbister & Nass, 2000; Leary, 1957; Sullivan, 1953). In comparison to studies supporting the similarity attraction rule, there are only handful of studies—especially in the area of mate selection (Winch, 1958) and commitment to a romantic relationship (Schmitt, 2002)—supporting the complementarity attraction rule (see Klohnen & Luo, 2003, for a review of the personality-based interpersonal attraction hypotheses.).

In the HCI literature, the similarity attraction rule has been supported in situations when people interact with disembodied social actors (Nass & Lee, 2001; Nass, Moon, Fogg, Reeves, & Dryer, 1995). In the case when people interact with embodied software agents, however, the complementarity attraction rule was supported (Isbister & Nass, 2000). It is still an open question, therefore, whether the similarity attraction rule holds in HRI in the same way as it is applied to most of previous HCI studies, or whether the complementarity attraction rule holds in HRI, because robots are, by definition, even more embodied than the software agents used in Isbister and Nass's study. Consequently, we set the following RQ in relation to Hypothesis 2:

> RQ: If people apply a personality-based social rule to a robot manifesting a personality, will they use the similarity attraction rule or the complementarity attraction rule?

Social presence: will feelings of social presence mediate people's social responses to robots?

The concept of presence has been argued to be at the heart of virtual experiences from the use of traditional media such as TV (Kim & Biocca, 1997; Lombard, Reich, Grabe, Bracken, & Ditton, 2000) to the ride of advanced virtual reality simulators (Biocca, 1997; Heeter, 1992; Loomis, 1992). After an extensive review of previous literature on presence, Lee (2004, p. 32) defines presence as "a psychological state in which the virtuality of experience is unnoticed." According to him, presence occurs when technology users do not notice either the mediated (e.g., broadcasted people or places on TV, telephone conversation partners) or the artificial (e.g., animated characters or places, software agents) nature of objects that are being experienced.

Based on three domains of human experience, Lee (2004) classifies three types of presence—physical, social, and self. Physical experience is the experience of physical entities or environments, and social experience refers to the experience of social actors including both humans and human-like intelligences. Finally, self-experience is the experience of one's own self or selves (see Goffman, 1963). When virtual physical entities, social actors, and selves are experienced as if they were real, feelings of physical, social, and self-presence occur, respectively.

Of the three types of presence, social presence has most implications in HRI because generating strong feelings of social presence during HRI can be regarded as the ultimate goal of designing socially interactive robots (see Breazeal, 2003; Fong et al., 2003). Without strong feelings of social presence during HRI, the experience of social robots will be nothing more than a *physical* experience of artificially embodied entities. For HRI to be a truly *social* experience, social robots should be experienced as if they were real social actors.

Presence scholars believe that feelings of social presence play a significant role in mediating technology users' attitudes, evaluations, and social responses toward the technology. In fact, a few recent studies have successfully shown that feelings of social presence play a crucial role in shaping technology users' social responses to computers (Lee & Nass, 2004; see Klein, 1999 also for the mediating effect of physical presence). In general, HRI is more intense social interaction than HCI because the former involves more human sensory systems and better AI engines. Therefore, we hypothesize that the mediating effects of social presence observed in HCI will be discovered in HRI too.

H3: Feelings of social presence will mediate robot users' social responses to a robot.

Tendency to form parasocial relationships: will it matter in HRI?

Finally, we try to find out possible individual factors influencing feelings of social presence and/or social responses to a robot. Many individual factors have been suggested to influence feelings of presence and social responses—for example, experience and familiarity with technology (Held & Durlach, 1992); gender (Lombard, 1995); mood, especially sensation-seeking mood (Apter, 1992); and the tendency to form parasocial relationships (Horton & Wohl, 1956; Jensen, 1992; Rubin & Perse, 1987). Of these, we focus on the tendency to form parasocial relationships because we believe this tendency strongly influences robot users' feelings of social presence and the magnitude of their social responses to a robot.

Parasocial relationship is a term originally used in the analysis of TV viewers' responses to TV characters. It is defined as a relationship some individuals form with a TV persona through frequent viewing (Horton & Wohl, 1956; Jensen, 1992). It stems from affective interpersonal involvement with a media personality (Rubin & Perse, 1987). Rubin and Perse pointed out that those who have a strong tendency to establish parasocial relationships with TV characters apply real-life social rules to the TV characters (e.g., talking to TV characters, project real-life emotions to TV characters). Unlike virtual characters in a TV set, robots are physically embodied and can be experienced through all human senses (e.g., you can touch, hug, and even smell robots). Therefore, we project that the tendency to form parasocial relationships will have strong influences on social responses to social robots.

Even though this tendency can be a very important covariate in studies based on the CASA research paradigm, it has never been tested in the previous CASA literature. In the current study, we provide the first test of possible effects of individuals' tendency to form parasocial relationships on their feelings of social presence and social responses to a robot. Thus, our final hypothesis is

H4: The tendency to form parasocial relationships will be a significant covariate for robot users' feelings of social presence and their social responses to a robot.

Method

Apparatus

In the current experiment, we used AIBO, a social robot developed by Sony. As a cute and cuddly dog, AIBO has 20 motors that enable it to walk, play soccer, sit, and lie down. It can also use its eyes, tail, ears, and lights to express a wide variety of emotions, consequently projecting a certain type of personality. With its speech recognition capacity and touchable sensors, AIBO is able to communicate with humans in a variety of autonomous ways. AIBO can recognize 53 simple phrases such as "good AIBO" and "see you." The sensors on AIBO's head, back, and chin also enable it to respond to humans when they are touched. In addition, AIBO also possesses memory and learning ability.

Participants

Students enrolled in communication courses at a large private university were recruited for the experiment with extra credit as their compensation. Several weeks before the experiment, students were asked to fill out an online personality questionnaire, which was a short form of two popular personality tests—the Myers–Briggs Type Indicator (see Murray, 1990) and the Wiggins (1979) personality test. The two measures were simultaneously used to maximize the correct measure of participants' personalities. From a total of approximately 200 students, 48 participants (aged 19–34, $M = 22.46$, $SD = 3.76$) with the most consistent scores on the two personality tests—24 extrovert and 24 introvert—were recruited to participate in the experiment. This procedure made it possible to exclude people with ambiguous personality. Only native English speakers were selected to ensure speech recognition accuracy.

Participants were randomly assigned to interact with either an extrovert or an introvert AIBO. Gender was approximately balanced across conditions. Participants were simply told that they would be enrolled in a study to examine their interaction with AIBO. All participants signed informed consent forms and were debriefed at the end of the experiment session.

Manipulation

As discussed before, both verbal and nonverbal cues were used to manipulate the personality of AIBO.

Four verbal cues—loudness, mean fundamental frequency, frequency range, and speech rate—are associated with the judgment of extroversion/introversion (Aronovitch, 1976; Nass & Lee, 2001, Pittam, 1994; Tusing & Dillard, 2000). It has been found that extroverts speak faster with louder, higher, and less monotonous voices than introverts (see Nass & Lee, for a summary of verbal cues of personality).

For the manipulation of verbal cues, we first used the Center for Spoken Language Understanding (CSLU) toolkit developed by the Oregon Graduate Institute (available at http://cslu.cse.ogi.edu) to produce extrovert and introvert synthetic voices of AIBO. Using an earlier version of the CSLU toolkit, Nass and Lee (2001) successfully manipulated the extroversion/introversion of synthetic voices used in an e-commerce Web site. Consequently, we used exactly the same vocal parameters that Nass and Lee used to produce both extrovert and introvert versions of AIBO's voice (see Table 1 for the details of each parameter).

As a secondary manipulation of verbal cues, we manipulated distinct melodies that AIBO produced when it understood users' commands or initiated its programmed behaviors. We created two types of AIBO melodies with the AIBO Master Studio program, a software authoring toolkit developed by Sony. Similar to AIBO's voice manipulation, AIBO's melody was manipulated in such a way that the extroverted AIBO had a louder volume, faster rhythm, more exciting musical tones than the introverted AIBO. Previous studies on the relationship between the extroversion and the preference for a stimulating music (Ciancarelli & Rawlings, 1997; Daoussis & McKelvie, 1986; Dollinger, 1993), which is marked by loudness, high tone, wider tone changes, and faster speed, also confirmed our manipulation.

Nonverbal cues, such as gesture, facial expression, posture, and body movement, are also important for the judgment of extroversion/introversion (Allport & Vernon, 1967; Hassin & Trope, 2000; Riggio & Friedman, 1986). Extroverts display more facial expressions and gestures, tend to have larger and more frequent body movements, and approach someone more readily than introverts do (Gallaher, 1992; Gifford, 1991; Isbister & Nass, 2000).

For the manipulation of nonverbal cues, the AIBO Master Studio program was used again because it enabled us to control AIBO's facial expression and body movement. Four nonverbal cues were simultaneously manipulated—(a) facial expression, (b) moving angle, (c) moving speed, and (d) autonomous movements (see Table 1 for the details of each manipulation).

AIBO is designed to provide facial expression by changing the light-emitting diode (LED) lights located in its facial area. Following previous findings that extroverts display more facial expressions than introverts do (Hassin & Trope, 2000;

Table 1 Manipulation of AIBO Personality

	Extrovert AIBO	Introvert AIBO
Verbal cues		
Voice	140 Hz fundamental frequency	84 Hz fundamental frequency
	40 Hz frequency range	16 Hz frequency range
	216 words per minute speech rate	184 words per minute speech rate
	Volume level set at 3	Volume level set at 1
Melody	High volume	Low volume
	Volume level set at 3	Volume level set at 1
	Fast rhythm	Slow rhythm
	Wide range of musical scale	Narrow range of musical scale
	Exciting mood	Quiet mood
Nonverbal cues		
LED lights	Colorful	Plain
	Frequent flashing	Occasional flashing
Moving angle	Two to three times wider than the introvert AIBO for the same act	30–50 percept of the angles compared to the extrovert AIBO for the same act
Moving speed	50–75% of the interpolation between motions compared to the introvert AIBO	Interpolation between motions 1.3 to 2 times longer than the extrovert AIBO
Autonomous movements	More frequent random walking and tail wagging when no command is given	Less frequent random walking and tail wagging when no command is given
	Motions in walking and tail wagging are faster, with wider angles	Motions in walking and tail wagging are slower, with narrower angles
	LED is colorful with more flashing in random walking and tail wagging	LED is plain with less flashing in random walking and tail wagging

Jäncke, 1993), the LED lights of the extroverted AIBO were manipulated to be more colorful and change more frequently in response to user inputs than those of the introverted AIBO.

AIBO has remarkable degrees of freedom in its body movements. Following previous studies that extroverts have larger, faster, and more frequent body movements than introverts (Gallaher, 1992; Gifford, 1991; Isbister & Nass, 2000), we programmed the extroverted AIBO to have larger motion angles, faster motion speed, and more frequent autonomous movements than the introverted AIBO. Below, we explain the manipulation of each body movement.

First, the extroverted AIBO's motion angles were programmed to be two to three times wider than those of the introvert AIBO. For example, in respond to a user's verbal command of "good AIBO," the extrovert AIBO could raise its front legs, making an angle of 107° from the ground. In contrast, the introverted AIBO was programmed to raise its front legs to only 30° from the ground. Second, the extroverted AIBO's motion speed was faster than that of the introverted AIBO (i.e., technically, it means that the extroverted AIBO has 50–70% shorter interpolation between motions than the introverted AIBO). For example, when AIBO danced in response to the user's verbal command of "dance," the interpolation between motions of the extroverted AIBO was 1 second, and the interpolation between motions of the introverted AIBO was 2 seconds. Finally, the extroverted AIBO was programmed to have more frequent and autonomous movements than the introverted AIBO. We programmed AIBO's autonomous movements to make it more lifelike. For example, when not responding to users' verbal or tactile commands, AIBO was programmed to walk and wag its tail randomly with frequent LED lights. AIBO's random behaviors were also programmed in such a way that the extroverted AIBO has wider motion angles, faster motion speed, and more colorful and frequent LED lights than the introverted AIBO.

A simple pilot test done to 10 graduate students confirmed that our personality manipulation worked. After observing verbal and nonverbal behaviors of either the extroverted or the introverted AIBO for about 5 minutes, all five students who observed the extroverted AIBO considered the AIBO to be an extrovert and the other half who observed the introverted AIBO considered the AIBO to be an introvert.

Procedure

Extroverted and introverted participants were randomly assigned to one of the four conditions in a 2 (AIBO personality: extrovert vs. introvert) by 2 (participant personality: extrovert vs. introvert) balanced, between-subject design.

Upon arrival at the laboratory, participants were asked to complete a preexperiment questionnaire measuring their tendency to form parasocial relationships. After that the participants watched a tutorial PowerPoint presentation (the file can be downloaded at http://www-rcf.usc.edu/~kwanminl/research/Aibo/Personality/instruction.ppt), which instructed the participants on how to interact with AIBO.

After the PowerPoint tutorial, each participant was randomly assigned to interact with either the extroverted or the introverted AIBO for 25 minutes. They were given a list containing 17 verbal commands that could be used to communicate with AIBO. Verbal commands of "show time," "dance," "cheer up," "good AIBO," and "let's play" would induce AIBO to respond with appropriate and complex movements, accompanied by melodies and flashing LED lights. Verbal commands of "shake paw," "go forward," "go backward," "turn right," "turn left," "right leg kick," "left leg kick," "stand up," "sit down," and "lie down" would induce AIBO to act accordingly. Verbal commands of "say hello" and "what's your name" would lead AIBO to answer "hello" and "my name is AIBO." Participants could also use three tactile interactive methods: touching AIBO's head, chin, and back. AIBO's internal sensors on its head, chin, and back would enable it to respond to tactile commands with combinations of movements, melodies, and flashing LED lights. Responses of both the extroverted and the introverted AIBO to each command would be the same in terms of property but different in terms of the degree of extroversion. For example, for a verbal command of "turn right," both the extroverted and the introverted AIBO would make a right turn, but the extroverted AIBO would turn faster with a wider moving angle than the introverted AIBO. All participants were required to check the commands list to make sure that they had observed all of the responses from AIBO and had tried out all of the commands.

After 25 minutes of interaction, participants were asked to fill out an online postexperiment questionnaire, which included items on their assessments of the personality, intelligence, and attractiveness of the AIBO they had interacted with, and their feelings of social presence during the experiment. Each question had an independent 10-point Likert scale. All participants were debriefed and thanked at the end of the experiment.

Measures

Extrovertedtness/introvertedness of AIBO was an index composed of six Wiggins (1979) personality adjective items: cheerful, enthusiastic, extrovert, introvert (reversely coded), inward (reversely coded), and shy (reversely coded). The participants were asked to indicate their general impression of the AIBO by circling one of the 10 dots besides the above adjectives. The response scales were anchored by *not at all* (1) and *absolutely* (10). This index was used for the assessments of both AIBO's personality (α = .84) and participants' personality (α = .83).

The question of whether people would adopt the similarity attraction or the complementarity attraction rule when they interacted with social robots was tested in three aspects—social attraction of AIBO, perceived intelligence of AIBO, and enjoyment of interaction.

Intelligence of AIBO was an index composed of two adjective items: clever and competent (α = .78). The participants were asked to circle one of the 10 dots besides the above adjectives and the response scales were anchored by *not at all* (1) and *absolutely* (10).

Social attraction of AIBO was an index composed of three items: (a) I think I could spend a good time with this AIBO, (b) I could establish a personal relationship with this AIBO, (c) I would like to spend more time with this AIBO (α = .92). The response scales were anchored by *very strongly disagree* (1) and *very strongly agree* (10).

Enjoyment of interaction with AIBO was an index of three adjective items: *enjoyable, fun, and entertaining* (α = .88). The participants were asked to circle one of the 10 dots besides the above adjectives and the response scales were anchored by *not at all* (1) and *absolutely* (10).

Feeling of social presence was an index composed of seven items (α = .89). The participants were asked to indicate their feelings when they were playing with AIBO; (a) How much did you feel as if you were interacting with an intelligent being?, (b) How much did you feel as if you were accompanied with an intelligent being?, (c) How much did you feel as if you were alone (reverse coded)?, (d) How much attention did you pay to it?, (e) How much did you feel involved with it?,

(f) How much did you feel as if it was responding to you?, and (g) How much did you feel as if you and the AIBO were communicating to each other? The participants were asked to circle one of the 10 dots besides the above adjectives and the response scales were anchored by *not at all* (1) and *absolutely* (10).

Tendency to form parasocial relationships was measured by a scale with eight items (α = .76) in the preexperiment questionnaire and was taken as a covariate. The participants were asked to imagine at least one favorite person or character they had seen on TV, movie, computer/video games, a novel, a cartoon, or any kinds of media and then describe their relationship with that person or character on a response scale anchored by *not at all* (1) and *absolutely* (10). The specific items were (a) How much of the time when you see this person or character does he/she/it seem to talk directly to you?, (b) How much of the time when you see this person or character do you talk directly to the person or character as if he/she/it can hear you?, (c) How often do you think about this person or character when you are not seeing him/her/it?, (d) How often do you talk with others about this person or character when you are not seeing him/her/it?, (e) To what extent do you think of this person or character as you do a close friend?, (f) How often do you compare your own ideas with those of this person or character?, (g) How much do you feel close to this person or character?, and (h) How often as a child did you play pretend or make-believe?

Results

We conducted a two-way analysis of covariance (ANCOVA) with AIBO personality and participant personality as the between-subject factors and the tendency to form parasocial relationships as a covariate. Table 2 reports ANCOVA results including means, standard deviations, *F* values, and effect sizes for all dependent variables.

H1 was supported. We found that participants were able to recognize AIBO's personality successfully. The main effect of AIBO's personality was statistically significant, $F(1, 43) = 6.73$, $p < .05$, $\eta^2 = .14$.The extroverted AIBO was perceived as being much more extroverted ($M = 6.94$, $SD = 1.40$) than the introverted AIBO ($M = 5.86$, $SD = 1.31$). There was no main effect of subject personality or interaction effect (see Table 2). These results indicate that our manipulation of AIBO's personality was successful.

H2 was also supported. People applied a consistent social rule to AIBO when they interacted with it. In response to RQ, the compelling evidence shows a complementarity attraction effect rather than the similarity attraction effect in all dependent variables (see Table 2). More specifically, there was a significant crossover interaction between the AIBO's personality and the participant's personality for the perceived intelligence of AIBO, $F(1, 43) = 7.06$, $p < .05$, $\eta^2 = .14$. Introverted people considered the extroverted AIBO more intelligent than the introverted AIBO, whereas extroverted people considered the introverted AIBO more intelligent than the extroverted AIBO. Neither the participant's personality nor AIBO's personality has a significant main effect on the perceived intelligence of AIBO. There was also

Table 2 Analysis of Covariance Results From the Experiment

Dependent variables	*M* (*SD*)				*F* values and effect sizes			
	Introvert subject		Extrovert subject		Main effects		Interaction	Covariate
	Introvert AIBO	Extrovert AIBO	Introvert AIBO	Extrovert AIBO	Participant personality (P)	AIBO personality (A)	P × A	Tendency to parasocial relationships
Intelligence	3.85 (2.30)	5.67 (2.10)	5.35 (1.68)	4.20 (1.89)	.28, η^2 = .01	.15, η^2 = .00	7.06*, η^2 = .14	3.23†, η^2 = .07
Social attraction	2.89 (1.97)	3.69 (2.36)	3.03 (2.19)	1.52 (.69)	1.26, η^2 = .03	.98, η^2 = .02	5.11*, η^2 = .11	7.31**, η^2 = .15
Enjoyment of interaction	6.10 (1.40)	7.10 (1.24)	6.41 (2.38)	5.22 (2.35)	1.11, η^2 = .03	.09, η^2 = .00	3.97†, η^2 = .09	1.17, η^2 = .03
Social presence	4.88 (1.25)	5.61 (2.05)	6.16 (1.84)	4.69 (1.78)	.85, η^2 = .02	.98, η^2 = .02	5.17*, η^2 = .11	4.14*, η^2 = .09

†$p < .10$. *$p < .05$. **$p < .01$.

a significant complementarity attraction effect on the social attraction of AIBO, $F(1, 43) = 5.11$, $p < .05$, $\eta^2 = .10$. People evaluated AIBO to be more socially attractive when AIBO's personality was complementary to their own personality than when their personality and AIBO's personality were similar. No significant main effect was found. There was a marginally significant interaction effect with regard to the enjoyment of interaction with AIBO. People enjoyed their interaction with AIBO more when they interacted with an AIBO with a complementary personality than when one with a similar personality, $F(1, 43) = 3.97$, $p < .10$, $\eta^2 = .09$. Neither the participant's personality nor AIBO's personality had a significant main effect. With regard to social presence, we found exactly the same pattern—a significant complementarity attraction effect with no main effect, $F(1, 43) = 5.17$, $p < .05$, $\eta^2 = .11$ (see Table 2 for details).

A path analysis was conducted to answer H3—whether social presence has mediating effects on other dependent variables. In general, mediation needs to satisfy five criteria in order to be valid (Baron & Kenny, 1986, p. 1177). The first criterion is that the independent variable should have a significant effect on the mediating variable. Second, the mediating variable should have a significant effect on the dependent variables. Third, the independent variable must have a significant effect on the dependent variables when the dependent variables are regressed on the independent variable without the mediating variable. Fourth, when the dependent variables are regressed on both the mediating variable and the independent variable, the effect of the mediating variable on the dependent variables should remain significant. Finally, the effect of the independent variable on the dependent variables should decline when the dependent variables are regressed on both the mediating variable and the independent variable.

Figure 1 clearly indicates the strong mediating effect of social presence. Satisfying the first criterion of mediation, the independent variable—*personality match*

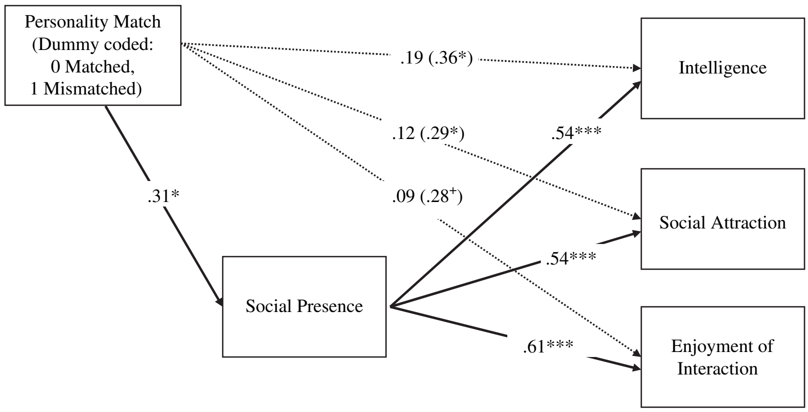

Figure 1 Mediating Effects of Social Presence. †$p < .10$. *$p < .05$. **$p < .01$.

Note: Standardized coefficients are inside arrows. Numbers inside parentheses are standardized coefficients when dependent variables are regressed on the independent variable alone without including social presence variables (copresence and psychological mediation) to the equations.

(dummy coded: 0 *similar*, 1 *complementary*)—was a significant predictor for the mediating variable, s*ocial presence* (β = .31, $p < .05$). Meeting the second criterion, social presence was a significant predictor for all dependent variables when it was the only predictor (perceived intelligence of AIBO [β = .60, $p < .001$], social attraction toward AIBO [β = .58, $p < .001$], and the enjoyment of interaction with AIBO [β = .64, $p < .001$]). The third criterion was also confirmed. When the dependent variables were regressed on the independent variable without the mediating variables, the independent variable significantly predicted perceived intelligence of AIBO (β = .36, $p < .05$), social attraction toward AIBO (β = .29, $p < .05$), and the enjoyment of interaction with AIBO (β = .28, t =1.97, $p < .06$). When both the independent (personality match) and the mediating (social presence) variables were used as predictors for a series of multiple regression analyses, we found unique patterns fully satisfying the fourth and the final criteria for statistical mediation (see Figure 1). First, the effect of social presence remained significant for all three dependent variables (perceived intelligence of AIBO [β = .54, $p < .001$], social attraction toward AIBO [β = .54, $p < .001$], and the enjoyment of interaction with AIBO [β = .61, $p < .001$]). Second, the effects of the independent variable on the perceived intelligence of AIBO (β = .19, *ns*), social attraction toward AIBO (β = .12, *ns*), and the enjoyment of interaction with AIBO (β = .09, *ns*) were no longer significant. In conclusion, the current path analysis confirms H3 and shows the mediating role of social presence in people's social responses toward AIBO.

With regard to H4, we found that the tendency to form parasocial relationships was a significant covariate for participants' feelings of social presence, $F(1, 43) = 4.14$, $p < .05$, $\eta^2 = .09$, and their evaluations of the social attraction of AIBO, $F(1, 43)$ =

7.31, $p < .01$, $\eta^2 = .15$. The tendency was also a marginally significant covariate for the intelligence of AIBO, $F(1, 43) = 3.23$, $p < .10$, $\eta^2 = .07$ (see Table 2).

We also conducted a separate set of ANCOVAs with participant's gender as the second covariate. Gender was not a significant covariate for all the dependent and mediating variables. Moreover, the addition of the gender covariate did not significantly alter the previous ANCOVA results. Therefore, we do not report the results from these new ANCOVA analyses.

Discussion

This study provides critical evidence that despite its clearly nonhuman origin, a social robot (AIBO) was responded to as if it manifested personality. Individuals identified a robot's personality and used personality-based social rules in their evaluation of the social robot. More specifically, individuals regarded a robot with a complementary personality as being more intelligent, more attractive, and more socially present than a robot with a similar personality. They also enjoyed the interaction more when they interacted with a robot with a complementary personality than when with a robot with a similar personality. These results have important theoretical implications to the study of HRI and the CASA research paradigm (Reeves & Nass, 1996).

The current study gives us confidence to expand the CASA research paradigm from HCI to HRI. In the context of HCI, a series of studies based on the CASA paradigm have found that people respond to computers and software agents as if they were real social actors. Textual content (Moon & Nass, 1996; Nass et al., 1995), agent appearance (Isbister & Nass, 2000), and agent behavior (Reeves & Nass, 1996) have been found to be effective tools for inducing personality-based social responses from users. Just as previous CASA studies have found that people respond socially to computers and computer agents, the current study found that people respond socially to social robots. Future studies on HRI, therefore, will be significantly advanced by adopting and applying sociopsychological findings of human-to-human interaction to human-to-robot interaction, which is how previous CASA studies on HCI have been advanced. For example, findings in social psychology such as social appropriateness and politeness (Reeves & Nass, 1996), spontaneous trait inferences (Todorov & Uleman, 2004), and automatic goal inference (Hassin, Aarts, & Ferguson, 2005) can be applied to predict possible interaction patterns in HRI. It will be reasonable to predict that people might try to provide socially appropriate responses to a social robot, after inferring its internal goals and traits based on its external behaviors.

Unlike previous CASA studies on HCI, which usually discovered the similarity attraction effect, the current study found the complementarity attraction effect instead. One possible explanation for this seemingly contradictory result is the difference between embodiment and disembodiment. Although most CASA studies on HCI are based on human interaction with disembodied software agents or computers, this study is on human interaction with physically embodied robots. Unlike interaction with disembodied agents or computers, which are usually limited to the audiovisual interaction modality, interaction with embodied agents such as robots is based on full human sensory modalities, including touch. Therefore, interaction with embodied agents is much more complicated and much more similar to human–human interaction in everyday life. Isbister and Nass (2000) pointed out that in human–human interaction literature, when people are presented with textual description of other people, one finds similarity attraction, and when people are involved in actual interaction with other people, one finds complementarity attraction. Following their argument, we believe that there is a fundamental difference between the interaction with disembodied agents and the interaction with embodied agents. Future studies should focus on the reason why this difference occurs.

This study also found that people's social responses toward a social robot are mediated by their feelings of social presence during their interaction with the robot. The mediating effect of social presence in people's social responses to computers or software agents have been discovered in the context of speech user interface (Lee & Nass, 2004) and computer game playing (Lee, Jin, Park, & Kang, 2004). As the first study to test and confirm the mediating effect of social presence in the context of HRI, the current study suggests that feelings of social presence during HRI are critical for the positive evaluation of a social robot. The converging evidence for the mediating role of social presence in different domains suggests the general importance of social presence in a wide variety of mediated and virtual experience. Future studies on human virtual experience should address the issue of social presence, whenever possible. Thorough consideration of social presence will be beneficial not only to the advancement of a theory on human virtual experience but also to a better design of new media (e.g., computer games, virtual reality systems) and artificial objects (e.g., software agents, robots).

Finally, the current study discovered an important individual factor affecting the magnitude of social responses during HRI. The tendency to form parasocial relationship was a significant covariate for participants' feelings of social presence and their evaluation of AIBO's social attraction. Future studies on social responses to communication and computer technologies will be significantly enhanced by measuring and statistically controlling this powerful individual difference.

In addition to the theoretical implications of the current study that have been discussed so far, the current study also demonstrates the value of multidisciplinary approach to the study of HRI. By applying a communication theory (CASA) and a concept (social presence), the current study advances our understanding of human responses to social robots, and provides many new insights for the design of social robots. Overall, we believe this study is an important step toward a comprehensive understanding of HRI.

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