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Close But Not Stuck: Understanding Social Distance in Human-Robot Interaction Through a Computer Mediation Approach

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ABSTRACT
We draw on the social information processing (SIP) model to argue that users' earlier experiences with online social environments tend to attribute human-like characteristics to robots. Specifically, when users engage in socially-charged electronic environments to interact and communicate electronically with others, they find ways to overcome the relative lack of cues to adapt to the medium; this includes in terms of reacting to emotional relationships (Walther, 1997). We hypothesize that individuals who have a high sense of online community, engage with avatars and have higher levels of competence communicating with information and communication technologies (ICT), are more likely to recognize humanlike cues in robots. This in turn leads them to accept robots as part of their social and physical environments. A "robotic" social distance scale was developed to measure willingness to accept robots, and the results based on this scale, from an empirical study of college students (N = 874) are explored. The findings show that whereas avatar engagement and sense of online community have a strong effect on robots acceptance, recognition of human-like characteristics partially mediates the association between these concepts; this is even after accounting for predictors expected to affect attitudes toward robots such as religion, gender, age and robots' appearance. The article ends by exploring the implications of this research for greater social acceptability of robots in various human domains.

KEY WORDS: computer mediated communication (CMC), social robots, social information processing model (SIP), information and communication technology (ICT), avatar engagement, sense of online community

INTRODUCTION

The idea of bringing robots into studies of social interaction has attracted scholars from diverse disciplines, especially since the 1990s when artificial intelligence developers "brought to life" embodied agents able to recognize one another, engage socially with humans and, through expressive abilities, influence people's perceptions (Dautenhahn & Billard, 2002). Using the metaphor of a cybernetic organism called cyborg, and based on the idea that the development of hybrid beings had reached a level where it was no longer possible to tell where human beings ended and machines began, Haraway (1985) was one of the first scholars to theorize about social outcomes in this new human-technology relationship. Haraway argued that the biological side and the mechanical/electrical side of the entire society has become so inextricably entwined, that we cannot even distinguish between what makes something "real" and what makes something "human or alive," which causes people to respond socially to these robotic inventions.

These themes have continued to be explored over the past quarter century as technological progress allowed human experience with robots to move from the entirely imaginary, that is, the realm of fiction and film, to artifacts in prototypical and even realized forms. Fortunati and colleagues (2003) delineated numerous ways in which robots and simulacra have become part of human conceptions, i.e., the realm of contemplation, as well as something through which meaningful interactions have taken place. Further expansion of these themes, including at the level of the human body, have been discussed by Katz and colleagues (2003) who demonstrated in numerous social domains the growing importance of electronic representations in social interaction. Laboratory and other behavioral observations on Human Robot Interaction (HRI) areas confirm impressions of people's inclination to invest "human-ness" in artificial entities. For instance, analyzing conversations in Sony's robotic dog AIBO's online discussion forums, Friedman, Kahn and Hagman (2003) found that 47% of the participants spoke about AIBO's biological essences; 42% of the forums' members spoke of AIBO as having intentional behavior; 38% of the commentators believed AIBO had feelings, and most incredibly 39% spoke of AIBO as being capable of being raised, developing, and maturing.

At the same time, personally relevant communication in today's society is increasingly mediated by information technologies. These mediational settings include a host of texting and conversational interactions, some of which are operated by software programs that mimic human conversation. Consider a typical trip by commercial airlines: Passengers can go through nearly an entire travel experience without having any direct or face-to-face (FtF) conversation with others (Polkosky, 2008). (Flight attendants are among the last vestiges of human-provided personal service, but as many of their activities as possible are being replaced by technology.) First, passengers buy their tickets on an Internet webpage. Then, if a passenger finds it necessary to phone the airline to confirm the flight status or address other issues, they are handled via a synthetic voice and speech recognition program. For most questions, they are transferred to an automated speech system programmed to provide the needed information. A few hours before the flight, travelers receive a text message on their cellphone alerting them about flight status; upon airport arrival they can check in and obtain boarding passes at touch screen kiosks, again without any personal interaction. Even on the plane, they may hear about the safety features not from a person but from cartoon images shown on a small video display monitor. The first human interaction they may have is mid-flight when they are asked for their beverage choice by the flight attendant (Polkosky, 2008).

We argue in this paper that there is a strong relationship between the role that technology has in mediating interpersonal relationships and how individuals respond socially to robots. Based on the social information processing (SIP) model, we predict that in the same way that users have the capability to adapt to the medium when they communicate electronically with others, they will find ways to overcome the relative shortage of cue systems and relate emotionally despite the lack of cues (Walther, 1997). "Technological savvy" individuals would assimilate these experiences and will be able to recognize more humanlike cues in robots. This in turn will lead them to accept robots as part of their social and physical environments. The paper is organized as follows: in the next section we discuss work that has already been carried out in this area, analyzing human-robots interactions from a Computer Mediated Communication (CMC) perspective. Then, drawing on previous research, we present factors found to affect subjects' attitudes toward robots. Third we describe our research methodology and the results of our empirical study. Finally, we draw conclusions and implications from the analysis.

ANTHROPOMORPHISM AND HUMAN-LIKENESS

For robots to engage in meaningful social interaction with people, it appears they need to be endowed with a degree of anthropomorphic or human-like qualities, whether in form or behavior (Duffy, 2003). To enhance anthropomorphic effects, "software agents" should have life-like characteristics and respond socially to stimuli, thus exploiting the social cues that humans naturally possess (Breazeal & Scassellat, 1999). The research literature on robotics has determined that the use of anthropomorphic "beings" leads human partners to treat humanoid social robots as real people (Brennan & Ohaeri, 1994). Nass and colleagues found that human-like robots invoke social-psychological processes, thus affecting one's behavior as if another human were present instead of a robot. In a series of experiments, Nass demonstrated empirically how technology could elicit social responses from humans, concluding that human-like characteristics (e.g., facial expressions, voice, emotions) act as cues that lead individuals to assign these agents to the category of "human" and eliciting comparable social responses from them (Reeves & Nass, 1996). The argument made by Nass and then expanded by Katz (2003) and others (e.g., Turkle, 2005), is that certain types of technological objects arouse a sense of intersubjectivity in individuals, which prompts them to respond socially to such entities (Cerulo, 2009).

Research from different areas has supported the Social Responses to Technology paradigm, signifying a strong anthropomorphic tendency to attribute human-like qualities to autonomous robots (Dautenhahn & Billard, 2002). People respond more socially to robots if they are capable of eye contact (Cassell et al., 1999), gesture observation (Cowley & MacDorman, 1995), natural language interactions (Kanda et al., 2004) and able to demonstrate self-directed behavior (Schermerhorn, Scheutz, & Crowell, 2008). However, it is still unclear which types of variables and factors at the individual level affect the recognition of human likeness in robots. Research has noted that previous experiences with technology and robots may have an influence in the attitudes and behaviors toward them. Woods et al. (2007) found people with a technological background are more likely to assign their own personality traits to robots than participants with a non-technology background. Those in this latter category had difficulty seeing that robots had a clearly identifiable personality. This aspect of relating is relevant in HRI since subjects almost universally prefer computers, robots, and avatars with personalities or social characteristics similar to their own (Nass & Moon 2000). Revealingly, people also generally prefer other human beings whom they perceive as having characteristics similar to their own.

Similarly, Nomura et al. (2006) conducted several experiments where subjects interacted with Robovie, a social robot, concluding that previous experiences with robots reduce uncertainty and anxiety in their interaction, leading participants to behave much more positively toward them. Likewise, in a cross-cultural study Bartneck et al. (2005) concluded that Americans were less negative interacting with robots than Mexican participants, based on the belief that Americans are more accustomed to both technology and to talking casually to new people. These findings are also consistent with research in CMC, which suggest that individuals with higher levels of competence with ICT tend to benefit more from relational uses of the technology (Campbell & Kwak, 2010; Hacker & Steiner, 2001).

CMC AS A FRAMEWORK FOR HRI

Computer-mediated communication (CMC) has been historically framed as an impersonal phenomenon that deindividuates participants, encouraging uncivil discourse (flaming) and group-based stereotyping (Kiesler, Siegel, & McGuire, 1984; Short, Williams, & Christie, 1976; Spears & Lea, 1992). Several theoretical frameworks have been presented by scholars to justify this stance. The Social Presence Model states that the fewer channels a medium has, the lower will be the social presence afforded by the medium. Low-channel CMC make it more difficult to build relationships than via face-to-face communication since the communication is perceived as cold and impersonal rather than warm and sociable (Short et al., 1976). Under these conditions, communication partners tend not to see the other as someone who could be a friend. As Rice and Love (1987) summarized, "as bandwidth narrows, media allow less 'social presence'; communication is likely to be described as less friendly, emotional, or personal and more serious, businesslike, or task oriented" (p. 88). Similarly, based on the Reduced Social Cues approach and Social Identity Model of Deindividuation Effects (SIDE), scholars argue that given the relative lack of social cues in CMC, individuals may find it easier to issue unpleasant decisions as they are divorced from the human consequences of their actions (Kiesler et al., 1984; Postmes, Spears, & Lea, 1998). "Deindividuation theory proposes that behavior becomes socially deregulated under conditions of anonymity and group immersion, as a result of reduced self-awareness" (Spears, Postmes, Lea, & Wolbert, 2002, p. 94). According to SIDE theory, under conditions in which participants' individual identity is not salient, group norms and identity are triggered, and this in-group identity leads to stereotyping of out-group members.

However, despite the limitations presented in CMC and its description as impersonal, hostile, and task-oriented, research shows that users have found ways to increase the richness of CMC and achieve socially oriented communication through it. Evidence establishes that CMC is sometimes used for explicitly social purposes (McCormick & McCormick, 1992), and communication partners seem to overcome the lack of social cues by a variety of means, including their interpretation of natural language, questions and disclosures, or imbuing their messages with social meaning through the use of emoticons, augmenting the meaning of textual electronic messages (Walther & D'Addario, 2001). Walther (1992, 1994) suggests an explanation for these discrepancies through an alternative perspective: The social information processing (SIP) model, which basically posits that impression development process takes longer in CMC, but if there is sufficient time, the differences between CMC and FtF communication will diminish, since users have the capability to adapt to the medium and find ways to overcome the relative shortage of cue systems. In other words, although the model recognizes that the lack of nonverbal cues in CMC limits the scope of exchanges, it holds that through more messages and time, communicators "learn" how to bring relational effects in CMC to the same level as in comparable FtF relationships, being able to see and recognize the humanity of the partner in the other side of the computer.

SENSE OF ONLINE COMMUNITY

The last decades have seen an unprecedented change in how people connect with their communities and form associations (Lin, 2001; Putnam, 1995; Wellman, Boase, & Chen, 2002). The concept of "sense of community," commonly used by both political scientists and political communication scholars to characterize the relationship between individual and the social structure to which they belong, has received an important amount of theoretical and empirical attention (Katz et al., 2004). This has especially been the case since the proliferation of new information and communication technologies, which according to researchers has provided technological changes for social relations and social structure (Katz & Rice, 2002), facilitating online relationships that supply the essentials of community such as support, sociability, information, social identities, and a sense of belonging (Wellman et al., 2002). Indeed, several studies have demonstrated the capacity of online communities to increase social ties and emotional support between users. Boase and Wellman (2006) concluded that the Internet has become one of the main channels to maintain physically distant relationships and to increase offline contacts because it can be used to arrange traditional meetings and strengthen relationships with people known offline. These positive impacts show how the Internet is supplementing rather than supplanting prior human communication (Katz & Rice, 2002; Wellman et al., 2003), demonstrating the potential as a tool for forming and maintaining weak tie networks (Ellison, Steinfield, & Lampe, 2007; Kavanaugh et al., 2005), extending social interactions and supporting community building (Williams, 2006).

Further, scholars have proposed new dimensions to the concept of "community," which used to be limited to groups confined geographically, to social ties that concatenate forming networks able to provide sociability, aid, support, and social control (Hampton, 2003). This new perspective gave researchers a framework to study the virtual interaction between individuals who share interests and adhere to similar customs generated in the Internet, suggesting that in the same way that people participate in offline settings to get support from others, to turn to CMC for advice, sharing of personal problems or to alleviate loneliness (Preece, 1999; Williams, 2006). Even more, researchers have adopted the idea behind a sense of community -- defined as a "feeling that members have of belonging, that members matter to one another and to the group, and a shared faith that members' needs will be met through their commitment to be together" (McMillan & Chavis, 1986, p. 9) -- to online environments, applying the term "sense of online community" (Katz & Aspden, 1997; Quan-Haase et al., 2002; Wellman et al., 2003). Importantly, these studies find that individuals who interact socially in virtual environments have been able to get similar social and emotional gratification in offline settings as well.

CULTURAL, DEMOGRAPHIC AND VIRTUAL DIFFERENCES IN ROBOTS PERCEPTION

Research has identified demographic and cultural differences among users in their interaction with robots (Halpern & Katz, 2012). In the Judeo-Christian tradition for instance, in contrast to other religious and philosophical traditions such as Buddhism, a clear division is made between living and dead entities (Shaw-Garlock, 2009). The Judeo-Christian world enforces a strict division between creatures that have a soul and animals and objects that do not, which is not the case for religions such as Japan's Shinto and India's Jains or naturalistic philosophies, where all worldly things may be deemed as alive and having a soul (Shaw-Garlock, 2009). From this view, social robots for the Judeo-Christian world would remain non-human and people might perceive them as incapable of assuming a position of moral equivalence, which may influence their ability to recognize human-likeness qualities. Regarding gender differences, research has found that males tend to think of the robot as more human-like (Schermerhorn et al., 2008). In contrast, females not only see robots as more machine-like but also characterize robots as less socially desirable. Nomura and colleagues conducted different experiments yielding consistent results that female respondents had more pronounced negative attitudes than male respondents toward situations involving interaction with robots (Nomura et al., 2009). Finally, there is a growing body of research on how the use of virtual self-representations affects many factors both within virtual environments and outside of them

(Ratan & Hasler, 2010). Similar to Nass and his colleagues, research has found that many of the rules that subjects apply to human-human interaction, are carried over to human-agent interaction (Pertaub, Slater, & Barker, 2002). Thus research hypothesizes that despite technical differences between dealing with robotic and virtual domains, today many issues behind the construction of successful social agents cut across the boundaries of virtual agent species (Holz et al., 2009).

SOCIAL DISTANCE IN ROBOTS

Researchers in robotics have started to explore how social robots are interacting with humans in diverse areas such as helpers for the elderly (Heerink, Kröse, Wielinga, & Evers, 2008), therapists for autistic children (Dautenhahn & Billard, 2002), home cleaners (Sung et al., 2007), receptionists in museums (Shiomi et al., 2006), and peer tutors in schools (Tanaka et al., 2006). On the other hand, human spatial behavior has been widely studied in social psychology, not only because of the role that proximity plays in personal interaction, but also because the proxy it plays in characterizing social distance or willingness that individuals show towards being associated with members of a designated group. Designed by Emory Bogardus (1967) to measure attitudes toward racial and ethnic groups, the Bogardus Social Distance Scale has remained one of the most commonly used methods of measuring prejudice (Wark & Galliher 2007). The present research assumes that similar rules apply for the interaction between people and robots. It would be natural to assume that individuals apply the same physical and social rules to robots who display levels of "social awareness" with human related roles. The "Robotic" Social Distance Scale we developed for this study modifies the Bogardus Social Distance Scale by adding statements related to willingness to be associated with robots.

RESEARCH STUDY

While previous research has examined how people respond socially to robots' appearance as well as the effects of human-likeness on attitudes toward robots, there has been little explanatory research on individual level factors that moderate this relationship, or how perceptions of human-likeness qualities in robots relate to other background aspects such as the use of communication and information technologies. Hence the present research explores the relationship between recognition of human-likeness qualities in robots, social uses of ICT and acceptance of robots based on the following research question:

For individuals, controlling for exposure to robot type, what is the relationship between activities that represent social uses of ICT and the willingness to accept robots as part of their social and physical environments?

Based on the idea that in the same way that users have the capability to adapt to a given electronic medium when they use it to communicate with others they will, when they communicate with robots, also find ways to overcome the paucity of cue systems and learn to relate emotionally despite the lack of cues (Walther, 1997). We also predict that individuals with a high sense of online community, high level of engagement with avatars, and high level of perceived competence communicating with ICT, would evince a greater level of recognition of more humanlike cues in robots. This, in turn, will lead to relatively higher acceptance of robots as part of their social and physical environments. This rationale could be summarized in the following hypotheses:

> H1a: Respondents with a history of high level of engagement with avatars will perceive more human-likeness qualities in robots.

H1b: Respondents with a high sense of online community will perceive more human-likeness qualities in robots.

H1c: Respondents with a high sense of competence using ICT will perceive more human-likeness qualities in robots.

H2a: Respondents with high levels of engagement with avatars will be more willing to accept robots as part of their social and physical environments.

H2b: Respondents with a high sense of online community will be more willing to accept robots as part of their social and physical environments.

H2c: Respondents with a high level of perceived competence using ICT will be more willing to accept robots as part of their social and physical environments.

Additionally, since previous research has found that robots' capacity to engage in a meaningful social interaction depends on the recognition of human-like qualities, whether in form or behavior, and the literature in robotics has shown that the use of anthropomorphic "beings" makes human partners more likely to treat humanoid social robots as real people, we also expect that:

H3: Recognition of human-likeness qualities will be positively related to willing to accept robots as part of their social and physical environments.

H4: Recognition of human-likeness qualities will mediate the relationship among sense of online community, avatar engagement and perception of competence using ICT with willingness to accept robots as part of their social and physical environments.

METHOD

Design Overview

A between-subjects empirical study was designed to identify human response to robots' appearances and their perceptions of robots. Participants were 789 undergraduate students (470 females, 283 males, 36 unidentifiable) enrolled in six communication courses at a large northeastern university, and ranged in age from 18 to 30 (M = 20.1, SD = 1.628). They were randomly divided in three groups and each group was exposed to an image of a different type of robot: Romeo, a French humanoid robot designed by Aldebara to assist elderly and disabled people; the AIBO robotic dog designed by Sony, and an android with an extreme robotic appearance. The original formatted images were embedded in the questionnaire. Then participants completed an online questionnaire that measured their willingness to accept robots, the degree of human-like characteristics they perceived in them and self-reports of their competence with information and communication technologies, engagement with avatars, and sense of online community. Demographic data were also obtained to control for gender, religion and age to ensure the sample is statistically representative.

Measurement

Dependent Scales

Human-likeness. This scale (Cronbach α = .88) was composed of eight items measuring recognition of human-like characteristics in the depicted robot. Questions such as "Most robots have emotions of their own," "Robots should have rights just like pets or people" or "I don't think it is right to mistreat or abuse a robot" were included in an 8-point Likert scale, with anchors 1 = strongly disagree and 8 = strongly agree.

Robotic Social Distance. The Bogardus Social Distance Scale was modified by replacing seven of the original statements (and which yielded a Cronbach α = .78). Similar to the original scale, participants who wish to maintain robots at a specified social distance are assumed to not wish for any closer contact; the further the social distance we would maintain, reflects reduced willingness to be associated with robots. This scale was composed of questions such as "It is fine to let robots teach in schools," "It is fine to have robots working in my neighborhood" or "It is fine to have robots living in houses with people." The items were measured in an 8-point Likert scale, with anchors 1 = strongly disagree and 8 = strongly agree.

Independent Scales

Perceived competence with information and communication technologies. Drawing from previous research (Campbell & Kwak, 2010), four questions were used to create a scale to measure the extent to which participants were competent with the use of technologies to communicate with others. Respondents were asked to state how much they agreed with each of the four statements: "I enjoy using my mobile phone to communicate with people," "I feel technology in general is easy to operate," "I am comfortable with the technical features of my mobile phone" and "It is easy for me to use my computer to communicate with others." An 8-point Likert scale, ranging from strongly disagree to strongly agree was used (Cronbach α = .76).

Engagement with Avatars. A scale was adapted from Ratan and Hasler (2010) that utilizes self-presence and social presence factors to provide a measurement of how people connect to virtual self-representations on an emotional and identity level (Cronbach α = .95). It is composed of five statements such as "When upsetting events happen to my avatar playing a video game, I also feel angry" or "When disgusting events happen to my avatar playing a video game, I also feel disgusted." Each item was rated on an 8-point Likert scale, with anchors 1 = strongly disagree and 8 = strongly agree.

Sense of Online Community. This scale was measured on an 8-point Likert scale adapted from Williams (2006) and Stravrositu and Sundar (2008) about sense of community in blogs (α = .86). The 14-item scale included questions about how participants felt about going online in general, such as: "I feel at home online," "I receive support from others online," and "I like to interact with others online."

Control Variables

Religion. Students were asked about their religion and we differentiated between Judeo-Christian religions (Catholics, Protestants, Jews, Muslims) and eastern religions (e.g., Hinduism, Jainism, Buddhism).

Use of Internet. Participants indicated how often they use the Internet via an 8-point scale ranging from 1 (do not use it at all) to 7 (almost all the day).

Second Life. A dichotomous variable for participation in Second Life was created to explore whether previous interaction with other users through avatars has had an effect on the dependent variables.

Age and Gender. All the regression models were controlled by age and gender.

RESULTS

Congruent with previous studies, participants in the humanoid condition survey recognized more human qualities in robots. A one-way ANOVA with the human-likeness scale as the dependent variable showed a statistically significant difference in participants' perceptions of human qualities in robots ($F(2, 744) = 13.53$, $p < .001$). Those who were exposed to humanoid robots recognized more human-likeness ($M = 3.25$, $SD = 1.39$), than in the android ($M = 2.93$, $SD = 1.43$) or the doggy robot conditions ($M = 2.73$, $SD = 1.25$). However, no significant differences were found between the android and doggy robot conditions. To explore whether individuals with high sense of online community, those who engage more with avatars and feel more competent communicating with ICT recognize more human-like cues in robots, the variables were bifurcated at their means in order to divide participants in two groups for further analysis. Three separate factorial univariate ANOVA were conducted. Results show that participants with high sense of community ($F(1, 723) = 13.53$, $p < .001$) and individuals who engage more with avatars ($F(1, 731) = 48.5$, $p < .001$) both recognized significantly more human-likeness in robots. However, no significant effects were found for individuals who perceive higher levels of competence communicating with ICT.

To determine whether there is a relationship between the independent variables and recognition of human-likeness qualities in robots, after controlling for the factors identified as predictors by previous research, hierarchical multivariate ordinary least squares (OLS) regressions were run to account for potential rival explanations and to assess the precise contribution of each block of predictors. Table 1 confirms the impact of the stimulus on the level of human qualities recognized in robots even in a multivariate level: individuals who were exposed to the android ($\beta = -.524$, $p < .001$) and dog robots ($\beta = -.288$, $p < .05$) saw significantly less humanity in robots compared to those in the humanoid condition. On the other hand, the block of demographic variables was not significant; neither gender nor religion was associated to recognition of human qualities. Similarly, avatar engagement ($\beta = .198$, $p < .001$) and sense of online community ($\beta = .129$, $p < .01$) were both positively related to recognition of human likeness, confirming that individuals who engage with avatars (H1a) and those who have a high sense of online community (H1b) can see more human-likeness in robots. However, individuals who feel more competent using ICT did not show higher levels of recognition of humanlike cues in robots, unlike what was predicted in H1c.

Table 1 OLS Regression Predicting Human-Likeness Qualities (*N* = 748)

	Human-Likeness (Block 1)	Human-Likeness (Block 2)	Human-Likeness (Block 3)
Doggy condition	-.524***	-.529***	-.454***
	(.131)	(.132)	(.125)
Android condition	-.288*	-.291*	-.217*
	(.126)	(.127)	(.121)
*R*2 (%)	2.2	2.2	2.2
Judeo-Christian Religions		-.163	-.1
(1= Yes)		(.120)	(.114)
Age		-.013	-.01
		(.03)	(.028)
Gender		-.06	-.057
(1 = Female)		(.108)	(.114)
*R*2 change (%)		.1	.1
Perceived competence ICT			-.067
			(.051)
Avatar engagement			.198***
			(.02)
Experience in Second Life			.242
(1= Yes)			(.151)
Sense of Online Community			.129**
			(047)
Internet Use			.16
			(.33)
*R*2 change (%)			9.4
Constant	1.9	2.3	4.24
Adjusted R2 (%)	2.2	2.3	11.7

Notes: b=unstandardized regression coefficients with standard error in parentheses are presented. R^2 change refers to the unique contribution of each block of variables controlling for the previous variables entered in the regression. † $p \leq .10$, * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$.

Concerning the impact that our independent variables have on willingness to accept robots as part of social and physical environments, Table 2 shows that engagement with avatars (β = .138, p ≤ .001) as well as sense of online community (β = .152, p ≤ .001) were both related positively, even after controlling for demographic and robots' appearance, supporting H2a and H2b respectively. However, perception of higher competence using ICT was not significantly related to willingness to accept robots as part of users' environments, unlike what was predicted by H2c. This means that those who engage more with avatars and have a high sense of community are more inclined to accept robots as part of their social and physical environments; however this is not necessarily the case for those who perceive higher competence using ICT.

Table 2 OLS Regression Predicting Robotic Social Distance (*N* = 748)

	Social Distance (Block 1)	Social Distance (Block 2)	Social Distance (Block 3)	Social Distance (Block 4)
Doggy condition	-.156	-.182	-.107	.015
	(.115)	(.112)	(.106)	(.102)
Android condition	-.152	-.119	-.05	.013
	(.105)	(.108)	(.104)	(.098)
R^2 (%)	.03	.03	.03	.03
Judeo-Christian Religions		-.193*	-.138	-.105
(1= Yes)		(.098)	(.089)	(.093)
Age		.014	.014	.016
		(.027)	(.024)	(.022)
Gender		-.563***	-.49***	-.512
(1 = Female)		(.101)	(.089)	(.084)
R^2 change (%)		5.5	5.5	5.5
Perceived competence ICT			-.026	-.007
			(.044)	(.041)
Avatar engagement			.138***	.82**
			(.024)	(.023)
Experience in Second Life			-.085	-.152
(1= Yes)			(.129)	(.122)
Sense of Online Community			.152***	.117**
			(04)	(.038)
Internet Use			.452	.404
			(.28)	(.269)
R^2 change (%)			8.3	8.3
Human-Likeness Qualities				.275***
				(.031)
R^2 change (%)				8.8
Constant	1.914	4.84	4.24	4.24
Adjusted R^2 (%)	.03	5.5	13.8	22.6

Notes: b=unstandardized regression coefficients with standard error in parentheses are presented. R^2 change refers to the unique contribution of each block of variables controlling for the previous variables entered in the regression.
† $p \leq .10$, * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$.

As shown in Table 2, the total variance in robots acceptance explained by the regression model was 22.6%. Interestingly, the block of robots appearance was almost insignificant in the model, whereas the demographic block explained 5.5% of the variance, confirming the importance of gender and religion as predictors for robots acceptance. The block of technological variables on the other hand, could explain 8.3% of the variance, almost the same percentage (8.8%) as recognition of human-likeness. In terms of the role that recognition of human likeness plays in robots acceptance, the results revealed in the last block of Table 2 support H3, providing evidence for the concept that human-likeness is a strong predictor of willingness to accept robots as part of social and physical environments (β = .275, p < .001).

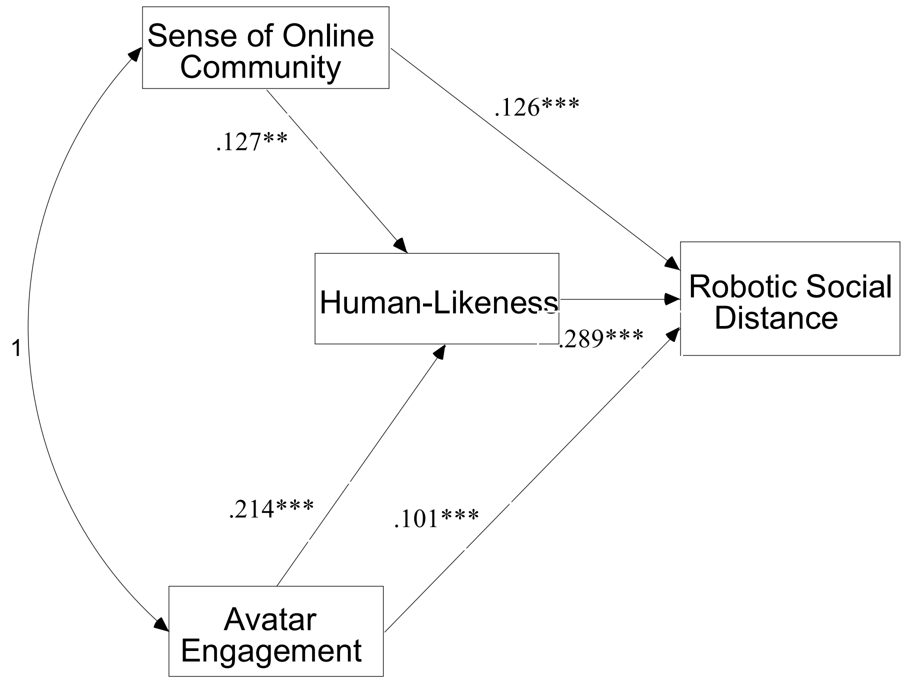

Figure 1 SEM Model for the Influence of Avatar Engagement and Sense of Online Community on Robots

In testing H4, when recognition of human qualities was introduced in the model (as Table 2 shows), the unstandardized betas of both avatar engagement and sense of online community declined significantly. This finding suggests the mediation role of human qualities in attitudes toward robots as predicted by H4. To formally test this possibility we ran a SEM model. Using human-likeness as endogenous variables, and robots distance as the exogenous variables, we found avatar engagement and sense of online community as the only significant predictors. The covariance was the fixed parameter. Although results in figure 1 show that all the variables were significantly related, the proposed model had a poor but acceptable fit ($\chi 2 = 8.1$ with $p = .07$ and $df = 1$, RMSEA = .09, CFI = .91, NFI = .92, TLI = .91). Since the direct effects of both variables (sense of online community and avatar engagement) were still significant when recognition of human qualities was introduced into the model, a bootstrap procedure used to generate a 95% confidence interval (2000 samples) and tests were conducted to assess the indirect effect of the variables. Results show that the indirect effect of sense of online community ($\beta = .021$) and avatar engagement ($\beta = .015$) were both low but significant at $p < .05$ level, supporting the idea that recognition of human like characteristics mediates the association between sense of online community, engagement with avatars and willingness to accept robots as part of social and physical environments.

DISCUSSION

This work applied a CMC approach to study human-robots interaction, adding a new dimension of recognition of human-likeness qualities as a potential intermediary process between social uses of ICT and willingness to accept robots in our social and physical environments. This step was based on the prediction that in the same way that users have the capability to adapt to the medium when they communicate electronically with others, finding ways for instance to relate emotionally despite the lack of cues (as explained in the social information processing model), individuals with a high sense of online community, and who engage with avatars and perceive higher levels of competence communicating with ICT, would be more inclined to perceive human-like cues in robots, which, in turn, will lead to acceptance of robots as part of their social and physical environments. Our results partially supported this communication based mediation model, with evidence of a positive relationship between two of the variables predicted (sense of online community and avatar engagement) and recognition of human-likeness and willing to accept robots as part of social and physical environments. Several aspects of these findings are worth discussing.

First, our study showed that exposure to humanoid designs increases recognition of human-likeness in robots but without affecting their attitudes toward them. In other words, participants exposed to the humanoid design could see more human-likeness in robots, but their willingness to accept robots as part of their environment was not affected by the appearance of the stimulus. We had hypothesized that following the same process of regular human interactions, in which recognizing other person's identity and discovering similarities are relevant to developing social relationships (Kanda, Hirano, Eaton, & Ishiguro, 2004), recognition of human-likeness in robots would lead individuals to accept them more. However, although in our model recognition of human-likeness was strongly related to robots acceptance, it could explain only an 8% of the variance, which means that more than 90% of the willingness to accept robots depends on other variables not necessarily related to human-likeness. In fact, gender and religion were both strong predictors for robot acceptance but not for recognition of human-likeness. This finding reinforces the idea that in our model there are factors more important than exposure to a visual stimulus of human-likeness. Rather these seem to be philosophical and cultural values held by respondents which affect their comfort and acceptance levels concerning robots in their routine social settings.

Regarding the relationship between the use of ICT to communicate with others and willingness to accept robots, it is noteworthy that whereas sense of online community and avatar engagement were positively related to recognition of human-likeness and "robotic" social distance, time spent using the Internet and previous experiences in Second Life, which shows whether participants had interacted previously with other users through avatars, were not significant predictors. One possible explanation might be related to the fact that the first two variables studied reflect how users interact with the technology, while the second set of variables reflects how much they use it. Research suggests that informational and social uses of the Internet encourage community involvement and foster civic participation (Norris, 2002; Shah, Cho, Eveland, & Kwak, 2005), arguing that it is not time spent using a particular medium that makes a difference but rather how individuals use it (Norris, 2002). Moreover, analyzing the same data that Putnam (2000) used to claim the negative effects of television on social capital, Shah, Mcleod and Yoon (2000) reported that informational uses of mass media are positively related to the production of social capital. Similarly, the analyses within subsamples also concluded that, among the youngest Americans, use of Internet for information exchange influences trust in people and civic participation. Consistent with this line of research, we found some variables contribute statistically to respondents recognizing human-likeness in robots; these were using the Internet to get support from other peers, share knowledge and meet others like them, and the feeling that the Internet made the respondent feel part of a larger community (all items represented in sense of online community). However, surprisingly, it was not necessarily the case that those who spent more time online also recognized greater human likeness in robots. Likewise, we found this positive relation only in those individuals who can engage emotionally with avatars, but not necessarily in those who only interact with them.

However, if individuals' capacity to recognize human-likeness is enhanced by the social use and engagement of ICT, as we discussed above, and our analysis considered more significant "qualitative" uses of ICT rather than quantitative (time spent), our study should have also found a positive relationship among individuals who perceive higher levels of competence communicating through ICT with others. Nonetheless, the results did not show this positive relationship, neither in recognition of human-likeness nor in attitude towards robots. One plausible explanation could be related to respondents' greater exposure to technology and even perhaps robots in real life; this could make respondents more aware of the abilities represented by technology but also of their shortcomings (Halpern & Katz, 2012). Bartneck et al. (2005) reasoned along these lines to explain why Japanese participants with a high degree of competence and experience using technology were more concerned emotionally vis-à-vis interaction with robots than were less technologically savvy participants.

LIMITATIONS

This study has limitations typical of undergraduate survey research, the most important of which is its lack of generalizability. By surveying only undergraduate students in a few classes at one university, the sample cannot be construed as being representative of either the entire university or of a larger population; hence, any generalizations must be limited. Students, for example, are traditionally more savvy with Internet and technology than other populations. Although we controlled for age, we had only relatively young people in the sample. We do not know if the results would be the same for senior citizens or a population that do not use Internet in general or social media in particular to develop human relationships. A more heterogeneous sample would be useful to better understand the model and to see the effects that different technological backgrounds may have on users. Another limitation was the exposure to the stimulus. Though we directed the respondent's attention to the figure with repeated questions, the power of the exposure would seem to be limited. This issue is discussed further when recommendations for future research are offered.

CONCLUSION

This research was conceived as an exploratory study to apply a communication oriented framework to study human-robot interaction. Based on the assumption that lean communicative channels (in terms of social cues) may enrich interaction between respondents as relationships evolve over time (by allowing people to learn how to communicate socially despite the lack of cues), we assumed that individuals who communicate electronically would be more likely to recognize social cues in robots. On the other hand, since previous work has demonstrated that even minimal human-like cues in human-computer interaction affect user behavior, and recognizing other people's identity are relevant aspects in developing social relationships, we predicted a similar outcome in HRI. Although the results from our study indicate that avatar engagement and sense of online community have a strong effect on willingness to accept robots in local social and physical environments, and recognition of human like characteristics partially mediates the association between these concepts, the poor fit of the model and the small variance explained by the recognition of human-likeness, suggest that this approach may not adequately characterize the situation.

Finally, based on our results two main suggestions for future studies should be considered to validate the CMC model elaborated here. First, potential research might draw dependent variables from a broader set of reactions towards robots instead of the robotic social distance scale explored here. More general attitudes towards robots for instance, might be useful to explore whether recognition of human-likeness plays a more determinant role in the variance explained by the model. Second, we also recommend using livelier and more animated representations of robots as a stimulus. These might include videos showing how robots interact with humans, instead of mere exposure to a single image. This aspect may not only increase recognition of human-likeness in robots, but also actuate an attitude change toward them. It would also presumably elicit a more accurate set of reactions on the respondents' part, yielding insight into potential acceptability for various social and interpersonal roles available for robots.

In sum, then, we have explored a range of predictors of the social reception of robots into everyday life. We have concluded that those with either experience with ICT representations of entities or pre-existing positive attitudes towards them (moderated through experience) will have more favorable attitudes towards robots in social roles. However, and rather surprisingly, recognition of human-like characteristics does not necessarily lead to a more favorable view of having robots involved in various social roles. This finding is provocative in that it problematizes several assumptions about the desirability of "human" or "android" qualities in robot design. Beyond the design implications are the communication ones. If human appearance is irrelevant to social acceptability, there is a much wider range of possible technological instantiations to make quotidian life more convenient. As well, it would mean that a broader range of automated services would be feasible in public settings such as hospitals and stores. Finally, it problematizes in interesting ways the nature of human social interaction and processes as they establish boundaries around in-groups and exclude out-groups. That said, these more philosophical extensions from the research lie outside the scope of the present article, though we anticipate addressing them elsewhere based on this and additional research.

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