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Effects of robot-human versus robot-robot behavior and entitativity on anthropomorphism and willingness to interact

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ABSTRACT

As robots become prevalent, people are increasingly interacting with multiple robots at once. Thus, it is important to not only examine how robot behavior toward humans affects interaction, but how robot behavior toward other robots affects interaction. We examine this in two studies. In Study 1, 630 participants from the USA and Japan viewed a video of one or more minimally social robots interacting differently towards humans (functionally/socially) and towards robots (single robot/functionally/socially). In Study 2, 71 participants from the USA and Japan watched videos of minimally social Sociable Trash Box (STB) robots in a cafeteria, with the robots using functional versus minimally social behavior toward humans and toward other robots. Results from the two studies indicate that robot behavior toward robots that was social, compared to functional, increased anthropomorphism of robots. Robot behavior toward humans that was social, compared to functional, increased positive emotions and willingness to interact with them. Finally, in these cooperative contexts between humans and robots, perceptions of robot group cohesiveness or “entitativity” increased positive perceptions or willingness to interact with robots. When robots are designed for positive human interaction (e.g., computer), they should behave socially toward humans; when robots should be considered intelligent (e.g., tutor robots), they may best be designed as social toward robots as well.

1. Introduction

Robots are being developed and becoming more prevalent in homes, schools, hospitals, and more, to help people in everyday life (e.g., Roomba; Forlizzi & DiSalvo, 2006; Jones, 2006), tutor robots (Gordon et al., 2016; Kory, Jeong, & Breazeal, 2013), Paro in nursing homes (Chang, Sabanovic, & Huber, 2013, 2014; Shibata, Wada, Ikeda, & Sabanovic, 2009), robots to assist in hospitals (Evans, Krishnamurthy, Barrows, Skewis, & Lumelsky, 1992; Ljungblad, Kotrbova, Jacobsson, Cramer, & Niechwiadowicz, 2012). As robots become more common, robots will not only be interacting with humans, but with other robots. This robot-robot interaction will give people more information about the robots and how they behave, which will sway human perceptions of them.

Social psychological research indicates that individuals perceive others based on their appearance and behavior (e.g., Bargh, Lombardi, & Higgins, 1988; Turner, Oakes, Haslam, & McGarty, 1994). Individuals are constantly updating their perceptions of others based on how these others interact with them and with third parties. A myriad of studies have shown that robot behavior toward humans matters for effective human-robot interaction (HRI; Parasuraman & Miller, 2004; Tapus, Tapuș, & Mataric, 2008). Recent studies also indicate that robot explicit communication with other robots (e.g., verbally, through the Internet) also affects HRI (Bera et al., 2018; Williams, Briggs, & Scheutz, 2015).

In this paper, we present two studies in which we examine robot functional versus minimally social behavior toward robots and toward humans, and how it affects HRI. In Study 1, participants in the USA and Japan watched videos of minimally social Sociable Trash Box (STB) robots in a cafeteria, with the robots using functional or social interaction styles toward humans and robots. From the data, we determine...
initial patterns and how they apply across two cultures. In Study 2, participants completed box-sorting tasks on a team with two STB robots, with the robots again using functional or social interaction styles toward participants and robots. With these studies, we examine how robot behavior toward humans versus robots differently affects perceptions of and interaction with robots.

2. Background

Numerous studies have indicated that people respond differently toward robots depending on the robots’ appearance and behavior, as well as the context of interaction (Goetz, Kiesler, & Powers, 2003, pp. 55–60; Kahn et al., 2011). However, recent studies examine not only individual robots’, but groups of robots’, effect on human responses (Admoni, Hayes, Feil-Seifer, Ullman, & Scassellati, 2013; Bera et al., 2018; Fraune, Sherrin, Sabanovic, & Smith, 2015; Krupp, Fraune, & Sabanovic, 2016; Leite et al., 2015). When robots interact in groups, compared to individually, there are more factors to take into account (Fraune et al., 2015; Fraune, Sherrin, Sabanovic, & Smith, 2019). For example, robots’ behavior toward other robots and the amount of cohesion of a group the robots will affect human responses toward them (Fraune, Sabanovic, Smith, Nishiwaki, & Okada, 2017b). In this paper, we seek to determine the effects of robot behavior toward humans versus the effects of robot behavior toward robots.

In particular, in this paper, we are interested in minimally social behavior toward humans and robots. We define minimally social behavior as small social behaviors that do not require humanlike interaction (e.g., nodding to acknowledge person), similar to previous papers on minimal design (Matsumoto, Fujiit, Goan, & Okada, 2005; Matsumoto, Fujiit, & Okada, 2006). This type of minimally social behavior can be performed by humanoid robots as well as robots with only a few social characteristics (e.g., eyes, hands, but not a full humanoid form – i.e., have a minimally social appearance (Matsumoto et al., 2005; Matsumoto et al., 2006)). Many of today’s robots use minimally social appearance (e.g., Jibo, Keepon) because it is cheaper than creating full humanoid robots and less likely to give humans false expectations about the robots’ social capabilities (M. K. Lee, Kiesler, & Forlizzi, 2010). For results to extend these robots, we chose to run the study with minimally social STB robots; Fig. 1 (Yamaji, Miyake, Yoshikoe, De Silva, & Okada, 2011).

2.1. Group effects

When people meet others, they categorize them instantly into social categories (e.g., gender, ethnicity) and in relation to themselves (e.g., ingroup or “my group,” vs. outgroup; Bargh et al., 1988; Turner et al., 1994). People respond more positively to ingroup than outgroup members, in terms of perceptions and behavior (Insko, Wildschüt, & Cohen, 2013; Sherif, 1936; Wildschüt, Insko, & Pinter, 2007; Wildschüt, Pinter, Vevea, Insko, & Schopler, 2003). This effect extends to HRI, with people preferring robots that are like them or ingroup members compared to outgroup robots (Eyssel, Kuchenbrandt, Bobinger, de Ruiter, & Hegel, 2012; Fraune, Sabanovic, Smith, 2017a; Kuchenbrandt, Eyssel, Bobinger, & Neufeld, 2011, 2013), or even humans (Fraune et al., 2017b).

Even if people do not fully categorize machines as ingroup members (Fraune, Sabanovic, & Smith, in press), when humans and robots share traits, goals, or positive experiences, participants respond more positively toward them (Bartneck, Van Der Hoek, Mubin, & Al Mahmud, 2007; Nass & Moon, 2000; Sandalov, Brandstetter, & Bartneck, 2016). For example, participants responded more positively toward robots that had humanlike traits (Eyssel et al., 2012; Fak, Fink, Price, Bass, & Sturre, 2012). Further, participants showed reciprocity to computers that did a good job of helping them (Nass & Moon, 2000). Therefore, if a robot behaves socially toward a person, that person may view it as more social and more positive.

Robot communication may exacerbate or mitigate this effect. When participants directly interacted with robots (rather than merely being in the same room with them; Fraune & Sabanovic, 2014), robot verbal communication, compared to nonverbal communication, elicited more perceptions of the robots as socially warm and likable (Tan, Reig, Carter, & Steinfeld, 2019) and less creepy (Williams et al., 2015). However, researchers have not yet examined how robot nonverbal, minimally social communication affects perceptions of the robots as humanlike or positive. In a previous study, participants perceived robots with minimally social interaction styles as less anthropomorphic and more negative when they were in groups than individual (Fraune et al., 2015).

It may be that when participants saw robots interacting with each other in minimally social ways, they perceived the robots as more machinelike or like outgroup members. However, in that study, robot behavior toward robots was not isolated from robot behavior toward humans, preventing strong conclusions. Therefore, we examine robot behavior toward humans separately from robot behavior toward robots in the study.

2.1.1. Entitativity

Related to robot behavior toward robots, robot group entitativity affects perceptions of and interactions with robot groups. Entitativity is defined as group cohesiveness, which includes group members sharing similar static traits (e.g., background, appearance, that are unlikely to change) and dynamic traits (e.g., goals, and outcomes, that may change frequently; Campbell, 1958). High-entitativity groups’ behavior typically aligns with the groups’ goals (Gergen, Gergen, & Barton, 1973; Insko et al., 1988, 2013, which influences people to perceive them as more effective. This means that the more robots look similar to each other, behave contingently with each other, and have similar outcomes, the more they will be perceived as a group and as competent (Fraune et al., 2017b).

Perceptions of high group entitativity have different results across contexts. In competitive contexts, outgroup entitativity increases fear and negative responses toward the group (Dasgupta, Banaji, & Abelson, 1999; Gaertner & Schopler, 1986; Insko et al., 2013). This is because a competent outgroup opponent is more dangerous than an incompetent outgroup opponent. Conversely, in cooperative or positive contexts, group entitativity increases positivity (Gergen et al., 1973; Johnson & Downing, 1979). This is because it is beneficial to have a competent group working with one’s own group.

This has been extended to HRI, with entitative outgroup robots being perceived as more negative than diverse outgroup robots (Fraune et al., 2017b). In a video study, participants perceived humanoid robots moving through a space as less friendly and comfortable, and more
creepy and unnerving, when they moved with high-compared to with low-entitativity (Bera et al., 2018). Conversely, it is expected (though not yet examined) that entititative robot groups that help people would be perceived as more positive than diverse robot groups. In our study, robots will have the purpose of helping people. We do not manipulate entititativity, but we expect that perceiving robot groups as having higher entititativity will increase positive perceptions of the robots.

2.2. Culture as universality check

Examining results across cultures can help determine how likely it is that the results are universal. That is, because there are many cultural differences between the USA and Japan, if people respond similarly to robots in both cultures, then it is likely that is a typical pattern of interaction toward the robots.

Typical differences referenced between Western cultures (e.g., USA) and Eastern cultures (e.g., Japan), include that the West is more negative about robots. This may be due to the negative portrayal of robots in the media (Kaplan, 2004) and negative stereotypes about robots in the West (e.g., “Robots will take my job,” Geraci, 2006). Participants from Western cultures also have different norms for etiquette (Salem, Ziadee, & Sakr, 2014) and prefer robots as functional tools, rather than friendly, human-like robots, (H. R. Lee & Sabanović, 2014; H. R. Lee, Sung, Sabanovic, & Han, 2012). However, some cross-cultural comparisons suggest fewer differences than expected based on implicit and explicit measures of attitudes toward robots (Bartneck, Nomura, Kanda, Suzuki, & Kennesu, 2005; Syrdal, Nomura, Hirai, & Dautenhahn, 2011, pp. 125–134). In our study, because the robots display only minimal social interaction, we do not hypothesize any interaction effects across countries. Instead, we examine responses in the USA and Japan to determine if responses to these behaviors are generally similar across cultures.

Although cultures also have different group dynamics, these will likely not affect this study. In Japan, people have more of a relational style of interaction (i.e., if a stranger is a friend of a friend, participants will be more positive toward them), whereas in the USA, people have more of a group-based style of interaction (i.e., if a stranger shares a group membership, participants will be more positive toward them; Brewer & Chen, 2007; Yuki, Maddux, Brewer, & Takemura, 2005). In this study, because the robots are strangers that share neither friends nor group memberships, we expect that cultural responses to groups will not create any interaction effects in the study, like in a previous study with robots that were not group members (Fraune et al., 2017b).

It should be noted that participants in Japan might show a stronger social desirability bias by responding more positively to survey questions overall (Bernardi, 2006; Si & Cullen, 1998). However, if there are no interaction effects (e.g., participants in one culture preferring certain robots more than the other culture, but other robots less than the other culture), then we will conclude that the effects of the study are generally universal in these two countries.

2.3. Video versus actual interaction

Using videos to collect data on HRI can be quick and efficient. Video data can reveal similar results to during actual interaction with robots (Druy, Keyes, & Yanco, 2007; Woods, Walters, Koay, & Dautenhahn, 2006), although certain differences occur in video versus real interaction (Bainbridge, Hart, Kim, & Scassellati, 2008, 2011). In this paper, in Study 1, we use video to collect data across countries, to find initial results and learn how universal the pattern of interaction in this paradigm is. Then, in Study 2, we use actual interaction with robots in one country to verify if the video results extend to actual interaction with robots.

2.4. Present study

In this paper, we include two studies to examine how robot behavior toward humans versus toward robots affects HRI. In Study 1, participants from the USA and Japan viewed videos of robots interacting with participants in university cafeterias. We manipulated robot behavior toward robots (single, functional, social) and robot behavior toward humans (functional, social) between participants. Then, participants answered survey questions about perceptions of robot anthropomorphism, entitativity, and emotional and behavioral responses. In Study 2, participants from the USA completed box-sorting games with robots, then answered the same survey questions. We hypothesize:

1. Anthropomorphism of robots: Participants will perceive robots as more anthropomorphic if robots behave more socially (i.e., SR and SH conditions), compared to robots that behave more functionally (i.e., FR and FH conditions). Specifically, this will differ with participants indicating that in SR and SH, compared to FR and FH:
   a. Behavior
      i. Robots behave more socially toward humans
      ii. Humans behave more socially toward robots
      iii. Robots behave more socially toward robots (in SR only)
   b. Rapport
      i. Robots show more social rapport with humans
      ii. Humans show more social rapport toward robots
      iii. Robots show more social rapport toward robots (in SR only)
   c. Agency and experience
      i. Robots display more agency
      ii. Robots display more experience
   d. Future robots
      i. Robots are more humanlike
      ii. Robots are less machine-like

2. Emotional and behavioral intention about robots: Participants will indicate more positive responses to robots that behaved socially toward humans, but functionally toward robots (i.e., SH and FR conditions), compared to robots that behaved functionally toward humans, but socially toward robots (i.e., FH and SR conditions). This difference will specifically be seen as participants rating:
   a. More positive attitudes toward robots
   b. More positive emotions toward robots
   c. Fewer negative emotions toward robots
   d. More willingness to interact with robots.

3. Entitativity of robots: Entitativity will affect participant responses as follows:
   a. Participants will rate robots as having higher entitativity when the robots include robots, but exclude humans (i.e., SR and FH conditions) than when the robots include humans or exclude robots (i.e., FR and SH conditions).
   b. Higher ratings of robot group entitativity will relate to more positive attitudes and emotions and more willingness to interact with the robots.

3. Study 1 method

3.1. Design

This is a 2 (Country: USA, Japan) x 3 (Robot behavior toward robots: none (single robot (1R)), Functional (FR), Social (SR)) x 2 (Robot behavior toward humans: Functional (FH), Social (SH)) between-subject study. We included the None control condition for Robot behavior toward robots by not having any other robots to behave toward (i.e., there was only a single robot present). In this study, we did not include a parallel None condition for the Robot behavior toward humans for multiple reasons. First, it is important to show the purpose of the robots (i.e., collect trash), and without humans putting trash in the robots, this behavior would not be seen; without seeing the robots complete their purposes, there would be a major confound in the additional conditions. Second, a major component of the study was how participants perceived robots, given how they might interact with humans; without seeing the
robots interact with humans, participants would have no conception of how such an interaction might go, and responses to the robots would likely include much greater variability. Third, with our 2 x 3 x 2 study, we already needed many participants; adding another condition (especially one with greater variability) would have drastically increased the number of participants necessary, which was not feasible for the current study. Future research should examine how people respond toward single or groups of robots in videos when no humans are around.

3.2. Participants

Participants from the USA (N = 333, 47% female, age M = 24.59, SD = 9.59) were recruited through the Indiana University Psychology participant pool for an online study and compensated with .5 credits toward their Introduction to Psychology class. Participants were also recruited online through social media using the snowball technique. Participants from Japan (N = 297, 7% female, age M = 21.55, SD = 3.35) were recruited through Toyohashi University of Technology classes. We excluded 24 participants from the USA and nine from Japan for failing the attention check (see Section 3.6 for details). Most participants in each Condition were from the majority country (USA 74.2%, Japan 97.9%; Table 1). The gender question was free response, and approximately 1% of participants identified as non-binary (e.g., “other,” “non-binary” “transgender”). See Table 2 for details.

3.2.1. Procedure

This study was approved by the Indiana University Institutional Review Board (IRB). Participants completed the survey on Qualtrics. They first clicked and the button to agree to the informed consent. Then, they watched an 85–95 s video according to condition. Finally, they completed survey items based on the video.

3.3. Robot platform

To perform our study with a “minimally social” robot, as discussed in Section 2, we used Sociable Trash Box (STB) robots (Figs. 2 and 3; Fraune et al., 2015; Yamaji, Miyake, Yoshiike, De Silva, & Okada, 2011), created at Toyohashi University of Technology’s Interaction and Communication Design (ICD) Lab. These robots have anthropomorphic traits (e.g., eye, arms), but are still far from humanlike. The STBs have no legs, but their motion is a gentle left-and-right that mimics swaying motion, and approached humans for trash. The robots bowed/nodded in thanks for trash being deposited. If humans shifted to the side, robots adjusted to follow them. In 1R conditions, only one robot looked around, motion, and approached humans for trash. Conditions differed as follows: In FR, robots moved as though other robots were objects with which to avoid collision. In SR, robots moved interdependently. They performed a “look around” motion, in which they turned left and right, and they got out of other robots’ ways. If they came face-to-face, they performed a forward-tipping motion to acknowledge another’s presence. Because this motion could be considered a bow (like in Japanese culture) or a nod (like in USA culture), we used the motion across cultures. In FH, robots approached humans for trash, stopped, and left regardless of the humans’ behavior. In SH, robots performed the “look around” motion, and approached humans for trash. Robots bowed/nodded to them when they reached the humans, and bowed/nodded in thanks for trash being deposited. If humans shifted to the side, robots adjusted to follow them. In 1R conditions, only one robot was visible in the video at a time. In other conditions, 2 to 3 robots were visible in the video at once. The robots were colored red, blue, and white. Video materials can be found here:

- 1RFH: https://osf.io/4c7ay/
- 1RSF: https://osf.io/4c7ay/
- FRFH: https://osf.io/4c7ay/
- FRSF: https://osf.io/4c7ay/
- SRFH: https://osf.io/4c7ay/
- SRSF: https://osf.io/4c7ay/

3.5. Measures

Participants were asked to “describe the robots with three descriptive words or phrases.” Then they rated robots on the below measures. Exact surveys can be found online at OSF (English: https://osf.io/7ajyr/; Japanese: https://osf.io/ec643/).

1. Anthropomorphism of robots. Participants reported the behavior and rapport of (1) robots toward humans, (2) humans toward robots, and (3) robots toward other robots (in group conditions). They also responded to measures of agency and experience, and what they thought of robots in the near future.

a. Social manipulation check. Participants indicated how “sociable” each group seemed to behave toward” each other group. Other distraction items were included (angry, cold, happy, interested, ignoring, sad). These distraction items are not included in the analysis, but were meant to obscure the purpose of the question. Participants rated these items on a scale from 1 (Not at all) to 5 (Extremely). This measure was made up for the study.

b. Rapport. Participants rated six questions about how they thought each group acted toward each other group (e.g., “To what extent do you think the humans had a feeling of mutual agreement with the robots?”) on a scale from 1 (Not at all) to 7 (Extremely). This measure was adapted from (Puccinelli & Tickle-Degnen, 2004) to include humans and robots.

c. Kosak Sociality of robots. Participants rated the STBs’ agency (five questions; e.g., “The robots are capable of planned action”) and experience (four questions; e.g., “The robots have complex feelings;” Kosak, Marsh, & Wegner, 2006).

d. Ezer. Participants rated what they thought robots in the near future might be like on Ezer analogy statements (e.g., “like a pet” or “like a toy”) on a scale from 1 (Not at all) to 5 (Extremely; Ezer, 2008).

Table 1

<table>
<thead>
<tr>
<th>Country</th>
<th>Ethnicity</th>
<th>Total</th>
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<tbody>
<tr>
<td></td>
<td>Caucasian, White, American</td>
<td>Japanese</td>
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<tr>
<td>USA</td>
<td>230</td>
<td>0</td>
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<tr>
<td>Japan</td>
<td>0</td>
<td>184</td>
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<tr>
<td>Total</td>
<td>230</td>
<td>184</td>
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</tbody>
</table>
2. Emotional and behavioral intention about robots
   a. Attitudes. Participants indicated on four questions how positive and negative they felt toward the robots (e.g., “I like these robots,”) on a scale from 1 (Strongly disagree) to 5 (Strongly agree; Cottrell & Neuberg, 2005).
   b. Emotion toward Robots. Participants rated twelve questions about emotions toward the robots (e.g., “I feel disgust toward these robots,” “I respect these robots,”) on a scale from 1 (Strongly disagree) to 5 (Strongly agree; Cottrell & Neuberg, 2005). We then performed a factor analysis to divide emotions into positive and negative (see Results section).
   c. Willingness to interact. Participants indicated on thirteen questions how they felt about interacting with robots in various contexts (e.g., “Hospital,” “Shopping”) on a scale from 1 (Definitely do not want to interact with robots in this context) to 5 (Definitely want to interact with robots in this context; Fraune et al., 2015).

3. Entitativity of robots
   a. Entitativity. Participants indicated on four questions how “groupy” they viewed the collection of robots to be (in the group conditions; e.g., “This group of robots is cohesive”) on a scale from 1 (Strongly disagree) to 7 (Strongly agree). This measure was taken from prior literature (Fraune et al., 2017a, Fraune et al., 2017b).

Participants indicated how many robots were in the video as an attention check. Participants were excluded if they indicated seeing only one robot in the group conditions. They were also excluded if they indicated seeing three or more robots in the 1R condition. We still included participants in the 1R condition if they indicated seeing two robots at once because in the video, participants saw one robot at a time, but sometimes the robots were different colors, and participants might have viewed that as two different robots. However, because the robots were always seen individually, and never in a group, we continue to consider this to be Single robot condition.

Finally, participants answered demographic questions (e.g., age, gender, technical experience).

4. Study 1 results

Data were analyzed in SPSS version 25. P-values less than 0.05 were considered statistically significant. All significant effects are reported. Overall, for most measures, Japanese participants gave higher ratings than USA participants. Because this was consistent across measures, as expected, but is not relevant to the research questions, we do not include it in the write-up below; however, the results appear in Table 3. Means, standard deviations, and Cronbach’s alpha for measures across all conditions appear in Table 4. Data can be found online at OSF through [link will be made public upon paper publication].

H1. Anthropomorphism of robots.

Robot sociality toward robots increased perceptions of social behavior (H1aiii) social rapport (H1biii) and agency (H1ci), partially supporting H1. Unexpectedly, groups of robots increased perceptions of future robots as both more like humans (H1di) and machines (conflicting with H1dii) than single robots.
This table indicates the main effects of Country on survey measures.

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<tbody>
<tr>
<td>F(1,484) = 30.955</td>
<td>&lt;.001</td>
<td>0.060</td>
<td>2.28 (1.00)</td>
<td>2.81 (1.07)</td>
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<tr>
<td>Robot-Human Sociality</td>
<td>F(1,484) = 25.878</td>
<td>&lt;.001</td>
<td>0.051</td>
<td>2.36 (1.20)</td>
<td>2.91 (1.13)</td>
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<tr>
<td>Robot-Robot Sociality</td>
<td>F(1,484) = 87.679</td>
<td>&lt;.001</td>
<td>0.153</td>
<td>2.16 (1.16)</td>
<td>3.16 (1.12)</td>
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<td>Human-Robot Rapport</td>
<td>F(1,486) = 187.479</td>
<td>&lt;.001</td>
<td>0.278</td>
<td>2.85 (0.89)</td>
<td>3.97 (0.86)</td>
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<td>Robot-Human Rapport</td>
<td>F(1,486) = 236.113</td>
<td>&lt;.001</td>
<td>0.327</td>
<td>2.35 (1.14)</td>
<td>3.92 (1.03)</td>
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<td>Robot-Robot Rapport</td>
<td>F(1,486) = 319.782</td>
<td>&lt;.001</td>
<td>0.186</td>
<td>2.97 (1.51)</td>
<td>4.36 (1.24)</td>
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<td>Robot Agency</td>
<td>F(1,486) = 19.224</td>
<td>0.010</td>
<td>0.024</td>
<td>2.98 (1.37)</td>
<td>3.45 (1.07)</td>
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<td>Robot Experience</td>
<td>F(1,486) = 208.288</td>
<td>&lt;.001</td>
<td>0.300</td>
<td>1.62 (1.07)</td>
<td>3.06 (1.08)</td>
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<tr>
<td>Ezer: Human-like</td>
<td>F(1,486) = 5.016</td>
<td>0.026</td>
<td>0.01</td>
<td>2.73 (0.49)</td>
<td>2.82 (0.41)</td>
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<tr>
<td>Ezer: Machine-like</td>
<td>F(1,486) = 11.815</td>
<td>0.001</td>
<td>0.128</td>
<td>3.02 (0.72)</td>
<td>2.84 (0.64)</td>
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<tr>
<td>Willingness to Interact</td>
<td>F(1,486) = 59.199</td>
<td>&lt;.001</td>
<td>0.109</td>
<td>2.74 (0.61)</td>
<td>3.15 (0.50)</td>
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<tr>
<td>Attitude</td>
<td>F(1,486) = 9.514</td>
<td>0.002</td>
<td>0.019</td>
<td>3.62 (0.86)</td>
<td>3.80 (0.80)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative Emotion</td>
<td>F(1,486) = 0.577</td>
<td>0.448</td>
<td>2.02 (0.71)</td>
<td>1.97 (0.57)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive Emotion</td>
<td>F(1,486) = 140.675</td>
<td>&lt;.001</td>
<td>0.224</td>
<td>2.91 (0.86)</td>
<td>2.03 (0.70)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sympathetic Emotion</td>
<td>F(1,486) = 0.18</td>
<td>0.894</td>
<td>0.38 (0.91)</td>
<td>2.39 (0.80)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entitativity</td>
<td>F(1,343) = 19.676</td>
<td>&lt;.001</td>
<td>0.054</td>
<td>4.08 (1.25)</td>
<td>4.64 (0.95)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Entitativity of robots

H1aii : On perceived robot sociality toward robots, there was a main effect of Behavior toward Robots (F(2, 484) = 9.720, p < .001, η² = 0.039), with people rating robot behavior toward robots as more sociable when they were SR compared to FR (p = .001) or 1R (p < .001). H1aiii : On perceived sociality of human behavior toward robots, there were two interaction effects of condition: There was an interaction effect of Behavior toward Humans x Behavior Toward Robots (F(2, 484) = 5.276, p = .005, η² = 0.021). There was an interaction effect of Country, Behavior toward Humans x Behavior Toward Robots (F(2, 484) = 3.268, p = .039, η² = 0.023). Participants viewed humans as behaving more sociably toward single robots in the SH than FH condition (p < .001). When divided by Country, this was true of USA participants (p < .001), but not Japanese participants. H1aii : There were no statistically significant differences related to robot behavior toward humans.

H1bii : On perceived robot rapport with robots, there was a main effect of Behavior toward Robots (F(2, 486) = 6.565, p = .002, η² = 0.026), with people rating rapport toward SR higher than they imagined 1R rapport with robots (p < .001). H1bi, H1bii : On perceived robot rapport with humans, and perceived human rapport with robots, there were no statistically significant differences.

H1ci : On sociality measures of agency, there was a main effect of Behavior toward Robots (F(2, 486) = 3.544, p = .030, η² = 0.014), with people rating agency higher for SR compared to 1R (p < .001). H1cii : On sociality measures of experience, there were no statistically significant differences.

H1di : On Ezer ratings of like a human, there was a main effect of Behavior toward Robots (F(2, 486) = 27.572, p < .001, η² = 0.102) with people rating robots as more like humans for SR (p < .001) and FR (p < .001) compared to 1R. H1dii : On Ezer ratings of like a machine, there was a main effect of Behavior toward Robots (F(2, 486) = 35.745, p < .001, η² = 0.128) with people rating robots as more like machines for SR (p < .001) and FR (p < .001) compared to 1R. To check whether people who rated the robots as like humans and like machines were the same or different, we ran a Pearson correlation on the two measures. There was a statistically significant positive correlation between the variables (r(497) = 0.721, p < .001).

4.1. H2. Emotional and behavioral intention about robots

First, we performed a factor analysis on emotion. This divided emotion into positive emotions (e.g., happy, excited), and negative emotions (e.g., sad, disgust), and sympathetic emotions (e.g., sympathy, pity).

There were no differences in attitudes (H2a) or emotions (H2b, c). Participants were more willing to interact with groups of robots than with single robots (failing to support H2).

H2a, b, c : There were no statistically significant differences in attitudes or positive or negative emotions toward the robots. H2d: However, there was a main effect of Behavior toward Robots (F(2, 486) = 15.122, p < .001, η² = 0.059), with participants rating higher willingness to interact with for SR (p < .001) and FR (p < .001) compared to 1R (Fig. 5).

4.2. H3. Entitativity of robots

Condition did not affect entitativity, failing to support H3a.

H3a : Condition had no significant effect on entitativity.

Higher ratings of entitativity related to more positive emotions and willingness to interact with the robots, supporting H3b.

H3b : Linear regression revealed a positive relationship between robot group perceived entitativity and positive attitude (F(1, 349) = 20.184, p < .001, standardized B (β) = 0.234), positive emotions (F(1, 349) = 5.379, p = .021, β = 0.123), sympathetic emotions (F(1, 349) = 8.215, p = .004, β = 0.152), and willingness to interact (F(1, 349) = 270.391, p < .001, β = 0.661). Because Japanese participants typically rated all measures higher than USA participants, we divided participants by country and ran the linear regressions. The same results were significant and in the same directions for both Japanese and USA participants.

5. Study 1 discussion

In Study 1, participants viewed videos of single robots or groups of robots behaving functionally or socially toward the other robots and functionally or socially towards humans. In general, participants viewed the robots as more anthropomorphic in the social conditions. Specifically, it was robot behavior toward other robots that most drove perceptions of them; when the robots were social toward each other, participants viewed the robots as more anthropomorphic, and viewed people as having higher rapport with the robots (H1). When the robots were in groups (regardless of their behavior) compared to individual, participants were more willing to interact with robots in the future (contrary to H2). Perceived robot group entitativity related to more positive responses to robots (H3).

Condition did not affect perceptions of robot group entitativity
Table 4
Participant ratings across measures as M(SD).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Cronbach’s alpha</th>
<th>USA</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FH</td>
<td>FR</td>
<td>SR</td>
</tr>
<tr>
<td>Perceived sociality of humans toward robots</td>
<td>(0.99)</td>
<td>(0.98)</td>
<td>(0.93)</td>
</tr>
<tr>
<td>x</td>
<td>1.89</td>
<td>2.23</td>
<td>2.60</td>
</tr>
<tr>
<td>Perceived sociality of robots toward humans</td>
<td>(1.20)</td>
<td>(1.23)</td>
<td>(1.03)</td>
</tr>
<tr>
<td>x</td>
<td>1.91</td>
<td>1.92</td>
<td>2.58</td>
</tr>
<tr>
<td>Perceived rapport of humans toward robots</td>
<td>0.824</td>
<td>2.70</td>
<td>2.73</td>
</tr>
<tr>
<td>Perceived rapport of robots toward that humans</td>
<td>0.905</td>
<td>2.24</td>
<td>2.29</td>
</tr>
<tr>
<td>x</td>
<td>1.23</td>
<td>1.15</td>
<td>1.16</td>
</tr>
<tr>
<td>Perceived rapport of robots toward robots</td>
<td>0.925</td>
<td>2.87</td>
<td>2.88</td>
</tr>
<tr>
<td>Agency of robots</td>
<td>(1.74)</td>
<td>(1.57)</td>
<td>(1.35)</td>
</tr>
<tr>
<td>x</td>
<td>2.67</td>
<td>3.01</td>
<td>3.02</td>
</tr>
<tr>
<td>Experience of robots</td>
<td>(1.44)</td>
<td>(1.51)</td>
<td>(1.27)</td>
</tr>
<tr>
<td>x</td>
<td>1.57</td>
<td>1.52</td>
<td>1.75</td>
</tr>
<tr>
<td>Humanlike (Ezer)</td>
<td>(1.27)</td>
<td>(0.96)</td>
<td>(1.09)</td>
</tr>
<tr>
<td>x</td>
<td>2.53</td>
<td>2.83</td>
<td>2.86</td>
</tr>
<tr>
<td>Machine-like (Ezer)</td>
<td>0.679</td>
<td>2.69</td>
<td>3.18</td>
</tr>
<tr>
<td>x</td>
<td>0.51</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Attitudes</td>
<td>0.852</td>
<td>3.47</td>
<td>3.65</td>
</tr>
<tr>
<td>Negative emotions</td>
<td>0.506</td>
<td>2.11</td>
<td>1.84</td>
</tr>
<tr>
<td>x</td>
<td>(0.77)</td>
<td>(0.64)</td>
<td>(0.78)</td>
</tr>
<tr>
<td>Positive emotions</td>
<td>0.708</td>
<td>2.83</td>
<td>2.93</td>
</tr>
<tr>
<td>x</td>
<td>(0.94)</td>
<td>(0.89)</td>
<td>(0.89)</td>
</tr>
<tr>
<td>Sympathetic emotions</td>
<td>0.601</td>
<td>2.42</td>
<td>2.40</td>
</tr>
<tr>
<td>x</td>
<td>(0.93)</td>
<td>(0.98)</td>
<td>(0.79)</td>
</tr>
<tr>
<td>Willingness to interact</td>
<td>0.827</td>
<td>2.51</td>
<td>2.77</td>
</tr>
<tr>
<td>x</td>
<td>(0.62)</td>
<td>(0.62)</td>
<td>(0.51)</td>
</tr>
<tr>
<td>Perceived robot group entitativity</td>
<td>0.721</td>
<td>4.23</td>
<td>3.87</td>
</tr>
</tbody>
</table>
(H3a). However, perceptions of higher robot group entitativity related to more positive attitudes and emotions and more willingness to interact with the robots (H3b). These findings likely occurred because the robots had a cooperative purpose with people (i.e., collecting their trash) and because in general, people had a more positive than average view of interacting with robots in a food establishment. This means that the robots were likely not threatening. Therefore, entitativity increased positive perceptions of them.

Unexpectedly, participants rated groups of robots, compared to single robots, as more like both humans and machines, regardless of how the robots behaved. This may be because groups typically cue people to categorize others (Turner, Hogg, Oakes, Reicher, & Wetherell, 1987). Therefore, when people see a group of robots, they may be more likely to categorize it as like a person, machine – or any other category, for that matter – compared to when they see an individual robot (Fraune et al., 2015). Conversely, it may be that there is an alternate idea of how the robots are viewed when they are individual that was not included on the scale. Future studies should examine other types of perceptions of robots.

Overall, effects were similar across countries. Although Japanese participants gave higher ratings than USA participants across measures, we do not consider this significant for the research questions. It is common that people of different cultures have slightly different styles of ratings (Bernardi, 2006; Si & Cullen, 1998). Further, the robots’ tipping-forward behavior, which we construed as a nod or bow of acknowledgment, may have been seen as a formal and polite bow in Japan, but an informal nod in the USA, which may also account for these main effects of country. Because we did not control for this, we primarily reported on only differential effects across cultures (i.e., interaction effects between cultures and other independent variables) or main effects of other independent variables.

One limitation of this study is that it was performed online. We expect that robot behavior toward humans would have a stronger effect during actual interaction. Therefore, we conduct Study 2 in the USA using actual interaction with robots.

6. Study 2 method

In Study 2, participants from the USA completed box-sorting games with robots, then answered survey questions from Study 1. With this study, we examined if Study 1 results generalize to actual interaction with robots. Some of the results of this study have been previously reported (Oistad et al., 2016); however, that paper included only two of the four conditions reported on in this paper.

6.1. Study design

This is a 2 (Robot behavior toward robots: Functional (FR), Social (SR)) x 2 (Robot behavior toward humans: Functional (FH), Social (SH)) between-subject study. See behavioral differences between conditions in Table 5.

6.2. Participants

Participants (N = 71, 42% female, age M = 19.20, SD = 1.30) were recruited from the Sona psychology participant pool at Indiana University. Participants received one psychology credit for interacting in the experiment. Participants were mostly Caucasian (Table 6) Gender was approximately evenly distributed across conditions (Table 7), as was computer experience.

6.3. Procedure

This study was approved by the Indiana University IRB. The experiment took place in the R-House, a home-like environment. Participants entered the lab individually and signed the informed consent document. The experimenter read a script that described that robots might be used in different everyday (rather than industrial) work contexts, such as caring for the elderly or teaching children. Participants were told they would complete a task similar to cleaning or construction “alongside” the robots. This wording was deliberately vague as to allow participants to define their relationship with the robots, avoiding pre-defining robots as servants or as tools. Participants were then led to the task room and were introduced to the two STBs. In both conditions, the experimenter

<table>
<thead>
<tr>
<th>Differences in robots’ behavior between conditions.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional</strong></td>
</tr>
<tr>
<td>Only approached participants at very beginning of first task</td>
</tr>
<tr>
<td>Did not nod or look around at boxes or participants/robots</td>
</tr>
<tr>
<td>Did not yield to participants/robots during task</td>
</tr>
<tr>
<td>Remained still during intermission</td>
</tr>
<tr>
<td><strong>Social</strong></td>
</tr>
<tr>
<td>Approached participants/robots and nodded at very beginning of first task</td>
</tr>
<tr>
<td>Nodded when passing participants/robots during task</td>
</tr>
<tr>
<td>Looked from side to side at boxes and participants/robots</td>
</tr>
<tr>
<td>Approached and nodded to participants/robots during intermission</td>
</tr>
</tbody>
</table>
said, “Robots, come meet the participant,” and the robots approached the participants. Social robots approached and greeted participants/robots (depending on condition) with a nod, while Functional robots simply approached the participants without greeting them.

### 6.3.1. Box sorting tasks

The study involved a box sorting task, an intermission, and a second box sorting task. The layout consisted of 11 boxes scattered in the middle of the room (there was a variety of light or dark and big or small boxes). The surrounding four walls each had one checkpoint and one goal, each identified by a specific box category (light boxes, dark boxes, big boxes, and small boxes; Fig. 5).

**Task 1.** For the first task, participants and STBs sorted the boxes by color. Participants took the boxes from the middle of the room to either the light or dark checkpoint (robots skipped the checkpoint), and participants and robots sorted boxes to the corresponding goal opposite it (Fig. 6). Checkpoints served as a handicap for the participants because the STBs were considerably slower in performing the task than the humans. Participants were instructed to move the boxes using a shuffling motion with their feet (rather than using their hands or kicking), similar to dribbling a soccer ball, to mirror how the STBs moved the boxes. Participants completed sorting one box before they could sort another box. The experimenter explained the task, instructed one STB to demonstrate how it would sort one box, asked participants to practice sorting one box, and then left the room for the duration of the task.

**Intermission.** After the first task, the experimenter reentered the room for an intermission to give participants and robots “reward” tokens supposedly based upon performance – which were later used for a measure (see Section 6.5). In actuality, participants always received two tokens following the first task to indicate they were in the top 50% of participants and four tokens following the second task (described below) to indicate that they are in the top 40% of participants. This was to suggest that their collaboration with the robot was successful.

**Task 2.** In the second task, teams sorted boxes by size instead of color. Using the same rules, participants and robots sorted the boxes, first to one side of the room to the checkpoint (for participants) and then to the opposite wall at the corresponding goal. Once both tasks were complete, the experimenter again rewarded robots and participants for their performance with tokens. Then Social (but not Functional) robots nodded goodbye to participants, and the experimenter led participants into the next room to complete a series of questionnaires about the experience.

Overall, each task took approximately 3 min. In that time, participants typically sorted about 7 boxes (task 1: $M = 6.2, SD = 2.6$, task 2: $M = 7.4, SD = 1.5$) and robots sorted about four (task 1: $M = 4.1, SD = 1.7$, task 2: $M = 3.5, SD = 1.5$).

### 6.4. Robots

The robots were the same STBs used in Study 1. Because the robots did not have the functional and interactive capabilities to perform in the study on their own, two researchers (experimenter and assistant) controlled the STBs using the Wizard of Oz (WoZ) paradigm. Drivers viewed the task through a bird’s-eye-view live-feed camera and controlled the robots wirelessly. While the experimenter introduced the robots, the assistant controlled both robots. Then, during the task, the assistant and the experimenter each drove one robot.

Drivers were instructed to drive the robots towards boxes that were closest to them and to sort them to the nearest goal. Social robots were made to nod or look around as they passed participants or robots, as per condition. Functional robots did not respond to others’ presence. When there were no more boxes to sort, the robots stopped moving. During the intermission, Social robots were made to approach participants and nod. Functional robots stood still and occasionally turned left or right to maintain a similar level of animation without interacting directly with participants.

### 6.5. Measures

Exact surveys can be found online at OSF (https://osf.io/ezpwh/). Most measures were the same as in Study 1, with the below exceptions.

1. **Robot autonomy check.** Participants rated how they thought the robots were acting (e.g., “pre-programmed,” “on their own,” “as a group,” “controlled remotely”) [redacted]. This question was asked last to avoid biasing how participants thought of the robots, but it is reported first to examine if participants thought they were interacting with robots or indirectly with humans (“controlled remotely”).

2. **Cooperation.** Because participants and robots worked together on a team task, we measured cooperation in two ways. However, we had no hypotheses about how cooperation might or might not differ across conditions.

   a. **Cooperation Survey.** Participants rated six statements (e.g., “The robots and I cooperated on the task”) on a scale from 1 (Strongly disagree) to 7 (Strongly agree). This question was included as a check that participants actually felt like they were cooperating with the robots (Oistad et al., 2016).

   b. **Prisoner’s Dilemma Game (PDG).** To measure behavioral cooperation, participants played a Prisoner’s Dilemma Game with the STBs, using the tokens they had won during the box-sorting task. If participants gave no tokens to the robots and the robots gave no tokens to the participants, then the participants would receive $0.60. If participants gave no tokens to the robots but the robots gave all their tokens to the participants, then the participants would receive $2.00. If participants gave half their tokens to robots and the robots gave no tokens in return, the participants won $0.20. If participants gave half their tokens to the robots and the robots gave half their tokens to the participants, the participants won $1.20. The robots could not make this decision on their own.
3. Distance from robots. The distance that people stood from robots before the game, during the intermission, and after the game was recorded. Distance was measured by dividing the room into a 3 x 4 grid. The human and the closest robot were assigned a box, and the number of boxes distant was counted. Each box was approximately 2 x 2. We used this as a measure of positive response toward robots, as previous literature has measured physical closeness to another as relating to positive response (Fazio, Effrein, & Falender, 1981; Hall, 1963). Therefore, with this measure, we add H2e: Participants will stand closer to the robots in FR and SH conditions, compared to SR and FH conditions.

4. Entitativity. Entitativity measures were expanded to include measures of static (e.g., “Members of the group have similar physical appearances”) and dynamic (members of the group experienced the same outcomes”) entitativity (Castano, Sacchi, & Gries, 2003; Kur-ebayashi, Hoffman, Ryan, & Murayama, 2012; Lickel, Hamilton, & Sherman, 2001; Bydell, Hugenberg, Ray, & Mackie, 2007; Rydell & McConnell, 2005; Yuki, 2003). The scale was the same as before (1–9).

7. Study 2 results

Data were analyzed in SPSS 25. P-values of less than 0.05 were considered statistically significant. In certain cases, we report “marginally significant” p-values of < .1. This is because of a pattern found across Ezer analogies, attitudes, and emotion that relates to and may help explain a statistically significant effect of behavior. We recommend interpreting the marginally significant results with caution. When equal variances could not be assumed based on statistical significance using Levine’s test for equality of variances, p-values were adjusted accordingly. Data can be found online at OSF through [link will be made public soon].

Most participants thought the robots were pre-programmed or otherwise acting on their own. Less than 10% thought that the researchers were controlling the robots remotely (Table 8).

Cronbach’s α for the scale was low (α = 0.604; Table 9). Even excluding the item that brought it down the most (participants’ contribution), it only slightly increased (α = 0.650). Overall, participants rated themselves as having cooperated with the robots (M = 5.703, SD = 0.84) condition than FRSH (M = 10.08, 10.53, SDs = 1.25, 1.44). H1a: Robot-human interaction” showed a significant interaction effect (F(1, 69) = 9.07, p = 0.025, n^2 = 0.071) indicating that participants rated robots as less ignoring in the SRSH (M = 9.53, SD = 0.84) condition than FRSH (M = 10.53, SD = 1.50, p < .001, p = .023) and SRFH (M = 10.56, SD = 1.38, p = .003, p = .011). H1bii, iii: Rapport did not differ significantly across conditions. H1ci: Robots’ agency was rated to be similar across conditions. H1cii: Experience showed an interaction effect (F(1, 69) = 4.96, p = 0.029, n^2 = 0.067; Fig. 7). Specifically, participants rated FRFH as having less experience than SRFH (p = .022).

7.1. H2. Emotional and behavioral intention about robots

People had marginally more positive attitudes (H2a) and emotions (H2b), and stood closer to (H2c), robots that behaved socially than functionally towards humans (partially supporting H2).

On survey measures, conditions had no statistically significant effects on attitude, emotion, or willingness to interact with the robots. However, because perceived robot entitativity had a strong relationship with these measures (see Section 7.3), we reran analyses using general, dynamic, and essence entitativity as covariates. In this case, there were marginal main effects of Behavior toward Humans, with people having more positive attitudes (attitude: F(1, 66) = 3.836, p = .054, n^2 = 0.055; dynamic entitativity: F(1, 69) = 3.018, p = .081, n^2 = 0.044) and positive emotions (positive emotions: F(1, 66) = 3.179, p = .079, n^2 = 0.046) toward SH than FH. For willingness to interact, both dynamic (F(1, 66) = 5.545, p = .022, n^2 = 0.078) and essence (F(1, 69) = 3.221, p = .077, n^2 = 0.047) entitativity were significant covariates to more willingness to interact, but conditions were not.

H2e: The behavioral measure, a 2 x 2 x 3 (Distance from robots) indicated a main effect of Behavior toward Humans (F(1, 57) = 6.928, p = .011, n^2 = 0.108), with participants standing closer to SH than FH robots (Fig. 8).

H1a: There was no effect of condition on perceived robot sociability (Table 9). Therefore, to examine if participants noticed any difference in robot behavior across conditions, we ran ANOVAs on other perceptions of robot behavior (angry, cold, happy, interested, ignoring, sad). H1a(i): Participants rated robot-robot interaction as more interested (F(1, 69) = 9.07, p = .020, n^2 = 0.076) and less ignoring (F(1, 69) = 9.07, p = .035, n^2 = 0.063) when robots were SR (Ms = 10.78, 9.87, SDs = 1.29, 1.21 respectively) than FR (Ms = 10.08, 10.53, SDs = 1.25, 1.44). H1a: Robot-human interaction showed a significant interaction effect (F(1, 69) = 9.07, p = 0.025, n^2 = 0.071) indicating that participants rated robots as less ignoring in the SRSH (M = 9.53, SD = 0.84) condition than FRSH (M = 10.53, SD = 1.50, p < .001, p = .023) and SRFH (M = 10.56, SD = 1.38, p = .003, p = .011). H1b, ii, iii: Rapport did not differ significantly across conditions.

H1c1: Robots’ agency was rated to be similar across conditions. H1cii: Experience showed an interaction effect (F(1, 69) = 4.96, p = 0.029, n^2 = 0.067; Fig. 7). Specifically, participants rated FRFH as having less experience than SRFH (p = .022). H1dii: Factor analysis distributed Ezer analogies into two categories: like a thing (appliance, machine, servant, toy, human reversed), like a teammate (assistant, friend, pet, teammate). There were marginal effects of condition on Ezer analogies. There was a main effect of Behavior toward Human (F(1, 69) = 3.180, p = .079, n^2 = 0.044), with participants viewing robots more like teammates in SH than FH. A marginal interaction effect (F(1, 69) = 3.257, p = .076, n^2 = 0.045) indicated that FRSH was viewed as slightly more like a teammate than FRFH (p = .011). H1dii: There was also a marginal interaction effect on viewing the robots as things (F(1, 69) = 2.963, p = .090, n^2 = 0.041), with FRFH as more like things than SRFH.

<table>
<thead>
<tr>
<th>Table 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>How participants thought the robots moved, according to condition.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Independent as a group</th>
<th>Pre-programmed</th>
<th>Controlled remotely</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRFH</td>
<td>4</td>
<td>2</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>SRFH</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>FRSH</td>
<td>3</td>
<td>1</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>SRSH</td>
<td>6</td>
<td>1</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>9</td>
<td>30</td>
<td>7</td>
</tr>
</tbody>
</table>
Table 9
Cronbach’s αs and descriptive statistics of measures across conditions: M(SD).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Cronbach’s α</th>
<th>FR</th>
<th>SR</th>
<th>FR</th>
<th>SR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Anthropomorphism of robots</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Perceived sociality of humans toward robots</td>
<td>1.00</td>
<td>2.47 (1.07)</td>
<td>2.33 (1.28)</td>
<td>2.71 (1.49)</td>
<td>2.84 (1.42)</td>
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<tr>
<td>Perceived sociality of robots toward humans</td>
<td>1.00</td>
<td>1.74 (0.87)</td>
<td>1.94 (0.87)</td>
<td>2.18 (1.33)</td>
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<td>Perceived sociality of robots toward robots</td>
<td>1.00</td>
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<td>2.83 (1.04)</td>
<td>2.18 (1.47)</td>
<td>2.83 (1.04)</td>
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<tr>
<td>Perceived rapport of humans toward robots</td>
<td>0.817</td>
<td>4.13 (0.85)</td>
<td>4.35 (1.15)</td>
<td>4.63 (1.27)</td>
<td>4.57 (1.39)</td>
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<tr>
<td>Perceived rapport of robots that humans</td>
<td>0.884</td>
<td>3.63 (1.24)</td>
<td>3.32 (1.28)</td>
<td>3.44 (1.50)</td>
<td>3.28 (1.38)</td>
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<tr>
<td>Perceived rapport of robots toward robots</td>
<td>0.879</td>
<td>4.32 (0.99)</td>
<td>4.54 (1.33)</td>
<td>3.88 (1.78)</td>
<td>4.37 (1.37)</td>
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<td>Agency of robots</td>
<td>0.763</td>
<td>4.84 (0.80)</td>
<td>4.58 (1.39)</td>
<td>5.09 (1.40)</td>
<td>4.54 (1.32)</td>
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<tr>
<td>Experience of robots</td>
<td>0.889</td>
<td>1.57 (0.87)</td>
<td>2.58 (1.56)</td>
<td>1.99 (1.23)</td>
<td>1.79 (0.88)</td>
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<td>Exz: Thing-like</td>
<td>0.679</td>
<td>3.83 (0.54)</td>
<td>3.43 (0.82)</td>
<td>3.47 (0.70)</td>
<td>3.65 (0.89)</td>
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<tr>
<td>Exz: Teammate</td>
<td>0.608</td>
<td>2.81 (0.77)</td>
<td>3.07 (0.81)</td>
<td>3.43 (0.57)</td>
<td>3.07 (0.72)</td>
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<td>2. Emotional and behavioral intention about robots</td>
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<td>Attitudes</td>
<td>0.944</td>
<td>4.04 (0.78)</td>
<td>4.14 (0.79)</td>
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<td>Negative Emotions</td>
<td>0.798</td>
<td>1.68 (0.53)</td>
<td>1.84 (0.85)</td>
<td>1.83 (0.64)</td>
<td>1.58 (0.39)</td>
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<td>Positive emotions</td>
<td>0.881</td>
<td>3.08 (0.53)</td>
<td>3.38 (0.91)</td>
<td>3.53 (0.71)</td>
<td>3.26 (0.68)</td>
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<td>Willingness to interact</td>
<td>0.891</td>
<td>3.02 (0.70)</td>
<td>3.43 (0.70)</td>
<td>3.31 (0.98)</td>
<td>3.42 (0.90)</td>
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<tr>
<td>3. Entitativity of robots</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>General entitativity</td>
<td>0.803</td>
<td>4.75 (0.76)</td>
<td>5.17 (1.07)</td>
<td>4.54 (1.33)</td>
<td>4.71 (0.89)</td>
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<td>Essence entitativity</td>
<td>0.789</td>
<td>5.43 (0.89)</td>
<td>5.43 (0.79)</td>
<td>5.49 (1.12)</td>
<td>5.50 (0.97)</td>
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<tr>
<td>Dynamic entitativity</td>
<td>0.762</td>
<td>5.34 (0.78)</td>
<td>5.58 (1.05)</td>
<td>4.81 (1.35)</td>
<td>4.89 (1.08)</td>
</tr>
</tbody>
</table>

Fig. 7. Average distance humans did from robots before, between, and after tasks, across conditions. Error bars represent standard error.

Fig. 8. Task 1 diagram. Participants took boxes to their corresponding colored checkpoint then the corresponding colored goal. Robots took boxes straight to the colored goal.
7.2. H3. Entitativity of robots

Participants perceived robots that were functional toward humans as more dynamic-entitative than those that were social toward humans, partially supporting H3a.

H3a : To analyze the entitativity measures, we first performed a factor analysis to determine if the scale could be used to measure essence and dynamic properties of entitativity. Excluding the general questions about entitativity (i.e., “groupness,” thought of as a whole, unified, cohesive), two dimensions emerged. One related more to essence properties (i.e., included questions about physical appearance, ease of joining and leaving the group, structure, and background – and unexpectedly, similar outcomes fell with this measure). The other related more to dynamic properties (i.e., included how much the robots influenced each other, common goals, similar personality, group organization, personally connected).

ANOVA on entitativity revealed there was no difference among conditions for general or for essence entitativity, but SH robots were rated as less dynamic-entitative than FH robots (F(1,69) = 5.87, p = .018, ηp² = 0.078). No other effects occurred.

Higher ratings of entitativity related to more positive emotions and willingness to interact, supporting H3b.

H3b : A series of linear regressions indicated that higher perceived robot group entitativity related to more positive attitudes, emotions, and willingness to interact with the robots. We used perceived general, essence, and dynamic entitativity as predictors of attitudes, positive and negative emotions, and willingness to interact. If the model came close to significance (p < .1), we reduced the less useful predictors (p > .2) to determine which type of entitativity significantly affected these measures. Results indicated that only general entitativity predicted more positive attitudes (F(1, 71) = 4.31, p = .040, β = 0.239), more positive emotions (F(1, 71) = 8.88, p = .004, β = 0.333), and fewer negative emotions (F(1, 71) = 6.35, p = .014, β = –0.287). Dynamic entitativity (p = .042, β = 0.309) and almost static entitativity (p = .061, β = 0.257) related positively to willingness to interact with robots, but only if general entitativity was included in the model (p = .168; F(3, 69) = 3.704, p = .016).

8. Overall discussion

In this study, participants played a game in a team with two STB robots that either behaved functionally or socially toward humans and toward robots. Results indicated that, like in Study 1, robot social behavior toward robots slightly increased social-like perceptions of them (H1). Unlike in Study 1, when participants actually interacted with (rather than viewed videos of) robots, it was robot behavior toward humans that affected human positive responses toward robots (H2). Specifically, robot behavior toward humans affected human behavior, with participants standing closer to robots that behaved socially than functionally toward humans. Similarly, in Study 2, social behavior toward humans marginally positively affected attitudes, emotions, willingness to interact with the robots – but only when accounting for perceived robot entitativity (H2). However, this difference might also relate to the different tasks of the robots (collecting trash (Study 1) compared to moving boxes (Study 2)). Like in Study 1, perceived robot group entitativity related to more positive responses to robots (H3).

In terms of anthropomorphism, participants rated robots as similarly agentic among conditions, but more capable of experience when they were in the Social toward Robots and Functional toward Humans condition than in other conditions, suggesting that inter-robot interaction, when not paired with interaction with humans, gives the robots more emotional agency. This is different from Study 1 in which robot sociality related to higher perceived agency. Overall, these two studies show that participants anthropomorphized robots more when they behaved socially toward other robots. It may be that this manifested in terms of agency in Study 1 and experience in Study 2 because of the team dynamic in Study 2. Future studies might specifically examine under which conditions people perceive robots to have more agency versus experience.

In Study 2, unlike in Study 1, robot behavior toward humans affected perceptions of them. This may be because participants actually interacted with the robots in Study 2, but not Study 1. It may be that participant responses toward robot-robot behavior in videos accurately reflects responses to it in the real world, whereas robot-human behavior is best studied in actual interaction.

In Study 2, robots that were functional toward humans were seen as slightly more dynamic-entitative than robots that were social toward humans. This is likely because humans could more easily feel like they joined the social robots’ group, which is a sign of a group with low-entitativity (Brewer, Hong, & Li, 2004). Robot-robot behavior did not significantly affect perceived entitativity. This indicates that overall, robots responding socially (as defined in this study) toward each other does not have a strong effect on perceived robot group entitativity, either when viewing or acting with robots. This will be helpful for robot designers because it means that robots can interact with each other without affecting perceptions of entitativity. Like in Study 1, higher perceived entitativity related to more positive responses toward the robots, as hypothesized. When robot interactivity is affected, people perceive them as more positive or negative depending on if people viewed the robots positively or not (Fraune et al., 2017b; Insko et al., 2013). This also confirms findings from previous studies that entitativity increases positive responses toward robots in positive contexts (Fraune, Sabanovic, & Kanda, 2019). Based on these studies, it is unknown if robot group entitativity has a smaller or larger effect on positive responses toward them than robot behavior toward humans. Future studies should specifically manipulate robot group entitativity in cooperative and competitive contexts to determine differences of these variables in effect size.

Overall, we found more differences in participant responses to robots during real-world interaction than in responses to video clips. Recently, it has become increasingly easy for researchers to put video clips on the Internet and collect vast amounts of data quickly. However, we encourage researchers to be cautious in making claims from online data. As seen in this paper, different components of HRI may have different important effects in the video study than in the real world study. For example, if we have performed only the online study, we would have missed how robot behavior toward humans affects human perceptions and actual behavior. Part of this difference may be due to participants performing a task with the robots during Study 2, and not Study 1. However, these types of differences also relate to how people will respond differently to robots in the real world. That is, people can actually interact with robots in the real world, and see robots responding to them, which will affect human responses toward the robots.

8.1. Limitations and future directions

Limitations include small sample size and some small effects, which should be interpreted with caution. Certain findings about condition’s effect on emotional responses toward robots in Study 2 only occurred with marginal significance when we used entitativity as a covariate. Stronger effects may have been found if the studies had included more participants.

In these studies, we used robots that were clearly helpful (e.g., included team interactions). Based on prior literature, we expect that if the robots were not helpful toward people – that is, neutral or negative – that people would perceive robots more negatively when they display high-than low-entitativity (Gergen et al., 1973; Insko et al., 1988, 2013).
In that case, it may be that social robot-robot behavior increases perceptions of robot group entitativity. Future studies should examine this.

We used minimally social robots in this study. The results of the study may not generalize to humanoid robots. Future research should examine how humanoid and mechanomorphic robots that have high or low entitativity change responses.

Because the results of Study 1 were consistent across countries, we found it reasonable to perform Study 2 in only one of the two countries. However, sometimes actual interaction may differ across countries in ways that only observing videos does not. Future research should replicate Study 2 in Japan.

9. Conclusion

In these studies, participants observed videos of (Study 1), or actually interacted as teammates of (Study 2), minimally social robots that were single (Study 1) or in groups (Studies 1 and 2). The robots behaved either socially or functionally toward robots and toward humans. Overall, the results indicate that robots’ social, compared to functional, behavior toward robots increased perceptions of robot anthropomorphism. Robot social, compared to functional, behavior toward humans increased positive attitudes, emotions, willingness to interact with, and actual physical proximity with, the robots. Finally, perceived robot group entitativity related to more positive attitudes, emotions, and willingness to interact with the robots in this positive interaction context.

Credit author statement


Declaration of competing interest

None.

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Appendix A. Supplementary data

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References


Kahn, P. H., Reichert, A. L., Gary, H. E., Kanda, T., Ishiguro, H., Shen, S.,
M.R. Fraune et al.
Lee, H. R., Sung, J.,
International Workshop on Robot and Human Interactive Communication, 2005.