The effect of group size on people's attitudes and cooperative behaviors toward robots in interactive gameplay

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Abstract—**This paper contributes to the study of interaction between groups of people and groups of robots by examining the effect of group size on people's attitudes and behaviors toward robots as interaction partners. Our work is motivated by psychological research on human intergroup dynamics, particularly the interindividual–intergroup discontinuity effect, which suggest that interactions among groups are more competitive than interactions among individuals. To test the discontinuity effect in the context of human-robot interaction, we conducted a between-subjects experiment with four conditions, derived by differentiating the ratio of humans to robots in the interaction (one or two humans interacting with one or two robots). Participants played a game with robots in which they were given a chance to exhibit competitive and cooperative behaviors, which we tracked along with measuring changes in participants' attitudes toward robots following gameplay. Our results show that people playing in groups behave more competitively towards the robots than individual human players. However, participants' attitudes toward robots did not change after the short-term interaction.**

I. Introduction

A common vision for the future of robotics—that various assistive robots will be working with us in the home, office, and other everyday environments [1]—is already being realized by robots that work alongside people, such as the Roomba [2]. Future users may expect to interact with multiple individual robots, as well as robotic swarms that can manipulate objects [3] or configure themselves into various domestic artifacts [4]. These examples suggest that interactions between humans and robots will frequently involve groups of people interacting and collaborating with groups of robots, in contrast to the common focus of HRI research on interactions between an individual person and a single robot.

While there has been little systematic research on interactions between groups of people and groups of robots, the social psychology literature suggests that people's attitudes and behaviors in group interactions are qualitatively different from those in dyadic interactions; for example, people exhibit higher levels of trust and reciprocation in dyadic interactions than in intergroup interactions [5]. The group discontinuity effect, in particular, asserts that competitiveness between groups is higher than competitiveness between individuals [6]. We can expect human-robot interaction to follow human-human intergroup dynamics in line with Reeves and Nass'[7] findings that people often treat computers and other technologies as social actors and apply social norms and rules to human-machine interactions, as well as extensive research showing that humans anthropomorphize robots (e.g., [8] and [9]). Robotics researchers are already developing ad hoc solutions to potential issues in intergroup human-robot interaction. For example, in the "Robot House" in Hertfordshire, UK, only one of three domestic robots operates at any given time [10], since the researchers' are concerned that users may be uncomfortable with multiple robots acting simultaneously. Accordingly, it is important to study how group effects play out in the context of human-robot interaction, particularly in cases in which people collaborate with robots.

In this paper, we study group effects in the context of human-robot interaction by investigating how people's tendencies to cooperate or compete with robots and their attitudes toward robots differ depending on the number of humans and robots involved in the interaction (one or two humans interacting with one or two robots). We present the results of a between-subjects experiment conducted to measure participants' implicit and explicit attitudes toward robots and their behaviors in a game in which participants could chose to compete or collaborate with the robots.

II. Background and Related Literature

A. Group size effects in human interaction

Psychological research has consistently demonstrated the existence of group size effects and inter-group bias in human interaction. Social categorization occurs when people are perceived as members of social groups rather than individuals and plays an important role in intergroup behaviors [11]. Tajfel found that people's categorizations of the social world into distinct social groups can induce ingroup favoritism and outgroup discrimination. Additionally, people assume that ingroup members hold more similar beliefs than outgroup members. Competition or conflicts between groups increase people's awareness of ingroup-outgroup memberships.

In addition to research on social categorization and intergroup relationships in social psychology, Schopler et al. [6] investigated attitude changes in inter-individual and inter-group interaction, called the "interindividual–intergroup

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discontinuity effect." In their studies, they used prisoner's dilemma games (PDG) to test person vs. person and group vs. group situations. By tracking the choices participants make during the game, they could evaluate people's behaviors as competitive or cooperative. This research verified that intergroup interactions are more competitive and less cooperative than interindividual interactions. Our study is informed by the findings and methodologies from such studies of group size effects in psychology.

B. HRI with groups of robots

Initial studies have shown that group size effects, already extensively studied by psychologists, also affect human-robot interaction. Eyssel and Kuchenbrandt found that social categorizations such as nationality can be applied to robots, with subjects preferring and anthropomorphizing the ingroup robot over the outgroup one [12]. Gong explored whether people perceive robots as a nonhuman outgroup by asking people to rank computer-generated characters with the appearance of white and black people or robots and found that many participants preferred robots over black avatars [13]. To study the positive affective evaluations of ingroup members, Kim asked participants to comparatively rate humans, robots, animals, and objects and showed that robots were rated closely to humans [14]. Xin and Sharlin considered group effects on the decision-making behavior of a person collaborating with four robots [15], but did not study the effect of group size on people's behaviors.

Our study focuses specifically on the effects of group size on people's attitudes and cooperative behaviors toward robotic interaction partners. While people's attitudes and behaviors toward robots have been studied extensively, there has been little research on how they are affected by group size and interaction dynamics. A common assumption in HRI research is that dyadic interactions will scale to larger group interactions [16]. Psychological research showing that inter-group interaction tends to be more competitive than dyadic interaction suggests that this may very well not be the case, as do initial results in the context of HRI.

III. Methods

We ran a between-subjects experiment with four conditions which varied by the number of humans and robots involved in the interaction (one or two humans and robots). Participants played a simple game with the robots in which they got several chances to cooperate or compete with the robots. We evaluated people's attitudes toward robots before and after the game as well as their behaviors towards the robots during the game to measure the effects of group size.

A. Participants

We recruited 41 participants with ages ranging from 19 to 49 through emails sent to university listserves, web bulletin postings, flyers on campus, and by word of mouth. Detailed demographic information for the participants is presented in Table 1. Ten participants have interacted with robots prior to the study, but only one participant had previously interacted with more than one robot at the same time.

The results of IAT and NARS tests administered before participants interacted with robots show that, on average, the participants held weakly negative implicit and explicit attitudes toward robots (see Table 2).

TABLE I. Demographic Information for participants

Table Head	Overall (n=41)	1H:1R (n=10)	1H:2R (n=11)	2H:1R (n=10)	2H:2R (n=10)
Age					
Mean	24.80	25.20	24.36	24.10	25.60
SD	6.19	8.95	6.20	3.54	5.78
Gender					
Female	48.8%	40%	36.4%	50%	70%
Male	51.2%	60%	63.6%	50%	30%
Education					
High school	7.3%	0%	18.2%	0%	10%
Some college	53.7%	70%	63.6%	50%	30%
Undergradate	12.2%	0%	0%	20%	30%
Graduate	26.8%	30%	18.2%	30%	30%
Major					
Computer/IT	12.2%	20%	18.2%	10%	10%
Natural Science	34.1%	10%	45.5%	30%	40%
Social Sci & Arts	53.7%	70%	36.4%	60%	50%
Occupation					
Student	70.7%	80%	54.5%	80%	70%
Non-student	24.4%	10%	45.5%	10%	30%
Prefer not to say	4.9%	10%	0%	10%	0%

TABLE II. IAT and NARS pre-test scores for participants

Table Head	Overall (n=41)	1H:1R (n=10)	1H:2R (n=11)	2H:1R (n=10)	2H:2R (n=10)
NARS[a]					
Mean	2.47	2.58	2.75	2.22	2.30
SD	0.58	0.56	0.33	0.58	0.72
IAT[b]					
Mean	-0.55	-0.48	-0.52	-0.43	-0.77
SD	0.44	0.47	0.45	0.53	0.28

a. Score of NARS: 1-5. NARS score>3: positive attitude; NARS score≤3: negative attitude

b. IAT score>0: positive attitude toward robot; IAT score<0: negative attitude toward robot

B. Design

The experiment was a between-subjects design. Participants were randomly assigned to one of four conditions: one human playing against one robot (1H:1R), one human playing against two robots (1H:2R), two humans playing against one robot (2H:1R) or two humans playing against two robots (2H:2R). We consider two people to be a group, as studies have shown there is no significant difference between the competitiveness of dyads and triads in relation to the discontinuity effect [17] and that two-person teams playing against each other in prisoner's dilemma games were indistinguishable from larger teams [18].

The main aim of the study was to *understand how the ratio of humans to robots affects participants' attitudes and cooperative behaviors towards robots.* To answer this question, we focused on exploring the following research questions and hypotheses related to group effects:

H1: People interacting with single robots will behave more collaboratively than those interacting with multiple robots.

H2: Two participants interacting with robots behave more competitively than single participants interacting with robots.

H3: People who interact with a group of robots will have a more negative impression of the robots they interacted with than those interacting with one robot.

H4: People who interact with a group of robots will have a more negative impression of the robots in general than those who interact with one robot. The negative attitude strength among the conditions will be: 2H2R>1H2R>2H1R>1H1R.

H5: People with more positive attitudes towards robots will be more likely to cooperate with robots than people with more negative attitudes towards robots

C. Materials

1) Robots

We used iRobot Creates, designed for applications in research and education, as our robotic platform (See Figure 1). Researchers controlled the robots remotely in Wizard-of-Oz fashion during the study by viewing the game room on their computers through video-feeds from cameras mounted on the walls of the room. Teleoperation was enabled by using Arduino boards mounted on the Creates that received instructions from Arduino serial monitors on the researchers' desktop computers via Xbee, a wireless communication shield.

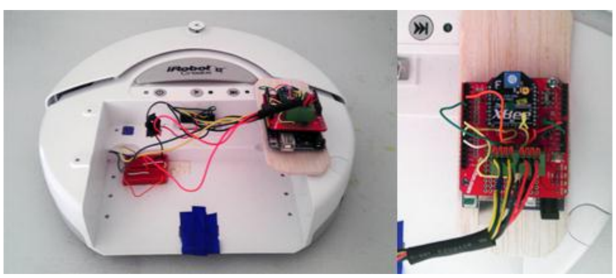

Figure 1. iRobot Create with Arduino mounted.

2) Questionnaires

Prior to interacting with the robots, participants completed a demographic questionnaire. Subjects were also asked to complete the NARS (Negative Attitude towards Robots Scale) [19] and a computerized Implicit Association Test (IAT) to measure their attitudes towards robots. NARS has been used widely in robotics research to evaluate subjects' explicit attitudes toward robots [20]. The IAT is widely used in psychological research [21] and was applied to HRI by MacDorman et al. to measure implicit attitudes toward robots [22]. These instruments were used both before and after the game to see if exposure to the robots had an effect on participants' attitudes toward robots. After completing the game task, participants also completed the Godspeed Questionnaire [23], which has been used to measure people's explicit perceptions of robots they had interacted with.

We created IAT tests for our study containing positively and negatively valenced verbal stimuli (e.g., joy, evil), and visual stimuli of photos of humans of different gender, age, and race, and different types of robots (See Fig. 2).

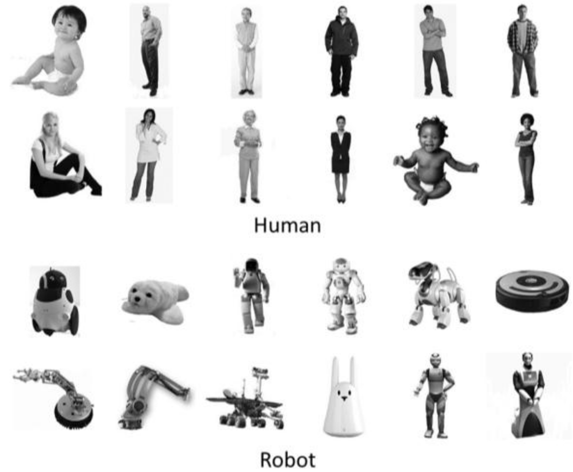

Figure 2. Human and robot images used in the IAT test.

3) Final Interview

Following the final questionnaire, participants were interviewed. The interviews were semi-structured and conducted in order learn which behaviors and qualities of the robots triggered emotions and judgments in the participants. The interviews began with questions regarding the participants' comfort and strategy during the game and conclude with questions regarding how the participants felt both about the robots in the game and robots in general.

4) Task: The Game

The interactive task participants performed with robots was designed in the form of a board game during which participants could choose to cooperate or compete with the robots on multiple occasions. Other researchers have also incorporated gameplay in the study of HRI: Fleischer et al. used soccer as a platform for testing human-robot interfaces [24]; Billard used games to explore social learning [25]; Xin and Sharlin designed a game test bed for studying HRI [15].

Figure 3. Two participants playing the game with one robot

The game board consisted of a series of squares laid in a looping path on the floor of the lab, with humans and robots acting as the game pieces. The aim of the game was to move around the game board collecting points until a team completes two laps. The number of squares moved was decided by rolling electronic dice: human participants used a remote control to roll the dice, while the researchers remotely rolled for the robots. We pre-arranged the numbers for each roll to ensure all participants had the same game experience, including eight "choice mode" rounds. Both teams landing on the same square triggered "choice mode" rounds, in which the teams face off in a prisoner's dilemma game (PDG), which allowed us to test participants' competitive and cooperative behavior. The method was introduced in 1952 by Flood [26] and has been used in similar experimental contexts [27].

During each normal round, teams were awarded one point for moving according to the dice; during choice mode rounds teams could earn more or less points by choosing to either keep their point for the round (competitive behavior) or give it to the other team (cooperative behavior). If both teams gave their points away, they received a cooperation bonus of three points each. If one team kept its point and the other team gave it away, then the team keeping its point received two points and the other team received zero points (Fig. 4). The robot teams' decisions during choice mode were calculated using Tit for Tat logic, meaning that the robot team was cooperative and gave its point away at the first choice mode and then mimicked the human team's preceding choice during the current round.

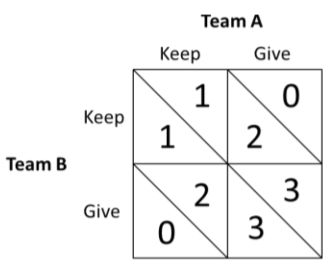

Figure 4. Possible point allocation after a "choice mode" round

At the conclusion of each game, we counted the number of times that the human team chose to cooperate with the robot team during the eight choice mode rounds. This number was recorded as the team's cooperative score. A cooperative score of 0 indicates that the team never chose to give their point to the robot during choice mode rounds. A score of 8 indicates that the team always gave their point to the robot during choice mode rounds.

D. Procedure

Participants were first introduced to our study and asked to fill in an Informed Consent Form, IAT, and a questionnaire of demographic information and NARS. Then they were escorted into the game room and left alone in the room to complete the game activity while researchers observed using wall-mounted cameras. Once the participants completed the activity, they asked participants to complete the Godspeed questionnaire, a NARS questionnaire, and a post-test IAT. Finally, we audiotaped semi-structured interviews with the participants about their experiences. At the conclusion of the study, participants were debriefed as to the purpose of the study and remunerated for their participation.

IV. Results

A. Cooperative behavior in relation to group size

We expected our participants' tendency to cooperate with the robots while playing the game to differ depending on the number of robots (H1) and the number of participants (H2). In order to test our hypotheses, we used a Generalized Linear Model to test for significant differences in the incidence of cooperative and competitive behavior among the four experimental conditions. We found that participants' cooperative behavior, as expressed in their cooperative score, differed significantly across the four conditions, $F(3) = 4.739$, $p = .007$. Tukey post-hoc comparisons of the four groups indicate that the 1H:1R case (M=4.56, 95% CI [2.977, 6.135]) had higher cooperative scores than the 2H:1R case (M= 0.60, 95% CI [-0.898,2.098]). Comparisons with the other groups, 1H:2R (M=2.727 , 95% CI [1.299, 4.156]) and 2H:2R (M=3.20 , 95% CI [1.702, 4.698]) were not statistically significant at $p<0.05$ (See Fig. 5).

Using GLM to test the relationships between the number of robots or humans and the cooperative scores, we also found that the human number significantly influenced people's decision to cooperate or compete, $F(1,38)=4.193$, $p=0.024$. When there was only one person interacting (M=3.55, SD=2.52), the participants cooperated more than when there were two people interacting with the robots (M=1.9, SD=2.57). However, the number of robots did not have significant impact on cooperative behavior, $F(1,38)=0.32$, $p>0.05$. While we cannot show that people interacting with two robot players were more competitive (H1), the number of human players influenced the participants' tendency to cooperate and compete (H2).

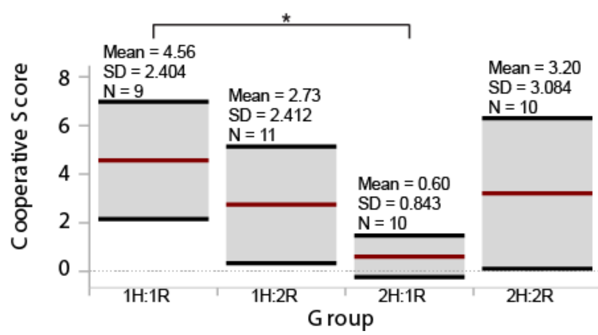

Figure 5. Cooperative scores per group. Red lines indicate mean score. Grey areas represent one standard deviation from the mean.

B. Attitudes toward robots in relation to group size

In order to find out whether the groups size affected people's attitudes toward robots, we used the GLM to test the change in the implicit (IAT) and explicit (NARS) measurement from before and after gameplay in all four conditions (H4). The results do not successfully support our hypothesis. We found no significant differences between conditions in the changes in IAT ($F(3)=1.58$, $p>0.05$) or NARS ($F(3)=0.13$, $p>0.05$). In fact, a repeated measures GLM analysis showed that there is no significant difference within the NARS ($F(1,37)=0.001$, $p>0.05$) and IAT ($F(1,38)=2.104$, $p>0.05$) scores measured before and after gameplay. We conclude subjects' explicit and implicit attitudes toward robots did not change as an effect of exposure to robots during the game play (H4).

We also did not find an effect of the subjects' pre-existing implicit and explicit attitudes toward robots on their competitive or collaborative behavior, as suggested in H5. Our test of the relationship of IAT and NARS measurements before the game with the incidence of cooperative and competitive behaviors did not yield significant results; IAT: $F(1,36)=0.19$, $p>0.05$ and NARS: $F(1,36)=0.016$, $p>0.05$.

C. *Perceptions of robot interaction partners*

To study people's perceptions of the robots they interacted with in the game, we used the Godspeed questionnaire, which includes five sections relating to "anthropomorphism," "animacy," "likeability," "perceived intelligence," and "perceived safety." Comparing the difference of the five sections between groups, we found that the only significant difference among conditions was in the "anthropomorphism" category, $F(3)=3.67$, $p=0.021$. Figure 6 shows that participants in the 1H:2R condition (M = 1.617, 95% CI = [1.237, 1.997]) tend to anthropomorphize the robots less than 2H:2R condition (M = 2.406, 95% CI = [2.059, 2.752]). The lack of significant differences in participants' evaluations of the robots' "likeability," "perceived intelligence," and "perceived safety" among conditions suggests that interaction with multiple robots did not have a negative effect on their evaluations of the robots (H3).

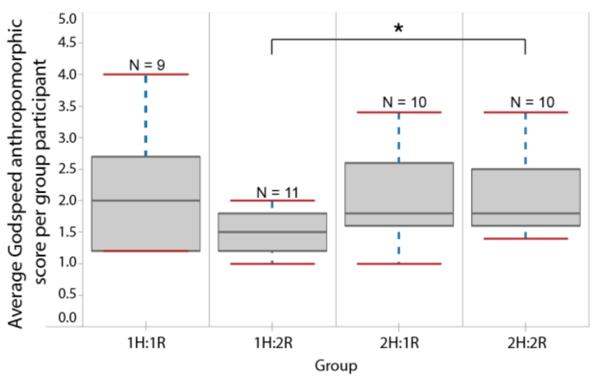

Figure 6. Box plot of responses from anthropomorphism section of Godspeed questionnaire. *groups show significant differences

D. *Interview*

An open-ended analysis of interviews with participants, coding for common discursive themes, showed that the nature of the game and the experimental environment can influence subjects' choice of behaving cooperatively or competitively. Participants also commented on the effect of the robots' appearance and interactivity on their gameplay.

Four participants said they played competitively and wanted to win because they were playing a "game," not because they were playing against robots. Two subjects thought the comfortable domestic environment made the game cooperative, friendly, or fun. One participant said she was able to play the game fairly as the robots were "neutral-looking" and that she would have been more competitive if the robot was evil-looking.

Fourteen participants mentioned that they wanted more interaction with the robots in the game. Six participants said that it would have changed their perceptions of robots or their behavior would have been "different" if the robots were more "human-like." Their meaning of "human-like" not only included the robots' morphology, such as having legs or arms, but also an ability to converse verbally during the game. Participants mentioned that "trash talking" and emotional reactions made playing games with friends fun, and suggested the same might hold for games with robots.

The participants generally felt the robots were more machines than social actors. Three people said the robots reminded them of a home appliance. Nine participants concluded that robots were emotionless but intelligent; one participant thought that adding emotion to robots would result in inaccuracy. Participants also recommended dangerous or repetitive tasks as appropriate jobs for robots, e.g., manufacturing, chores, heavy labor, or assisting humans in tasks that do not require "thinking."

V. Discussion

The main purpose of our study was to understand whether findings regarding group effects from human interaction, specifically Schopler et al.'s [6] discontinuity effect, translate into human-robot interaction. We explored how group interactions influence people's cooperative behaviors towards and perceptions of robots. Our results show that some of the effects seen in human-human interaction can also be seen in human-robot interaction, but also suggest that additional factors, such as the appearance and behavior of the robots, may have an effect on the strength of these effects in HRI.

Specifically, the results indicate the following in relation to our hypotheses:

- The number of people in the interaction significantly affected cooperative behavior with the robots, while the number of robots had no effect on cooperation. This result partially supports the interindividual–intergroup discontinuity effect in HRI. Participants' comments in the interviews suggest that the lack of effect of robot number may be due to the particular robots we used, which were non-anthropomorphic.
- Exposure to robots during the game had no effect on people's explicit or implicit perceptions of robots as measured by NARS and the IAT. This may have been due to the short-term nature of our participants' contact with the robots, as well as because of their non-anthropomorphic appearance and lack of direct interaction with the participants during the game.
- In contrast to our expectations, participants' existing negative or positive attitudes toward the robots did not have an effect on their decision to be competitive or cooperative during the game. This suggests that the dynamics of the interaction itself influence participant behaviors more strongly than prior attitudes.

We found some significant differences in cooperative behavior during human-robot interactions, partially supporting the application of Interindividual–Intergroup discontinuity theory to human-robot interactions relating to H2 (two people in a group will be more competitive than only one person), but the study results do not support our other hypotheses (H1, H3, H4, and H5).

Participants did anthropomorphize the robots more when they interacted with two rather than one robot, so there is an effect of robot number on perceptions of human-likeness, particularly when only one person interacted with two robots.

Our study had certain limitations. A larger numbers of trials may reveal further correlations among evaluated factors. Some findings in the interviews reveal other possible reasons that may have affected the expression of group effects we had expected during our study. We specifically chose to use non-anthropomorphic robots to decrease the possibility of confounds arising from specific aspects of the robot's appearance (e.g. cuteness) or behavior (e.g. speaking). However, a number of subjects mentioned that they had expected the robots used in the experiment to be more "human-like," while others mentioned that they would have liked to be able to converse with robots during the game as they might have done with people. Using more anthropomorphic or socially interactive robots may have caused stronger group effects. We can also consider adding emotional responses to the robot. Participants mentioned they perceived the robots as rational machines and did not mind winning the game because the robots would not be upset. We plan on investigating the effects of these factors in future studies. We can also test group effects in different game designs besides prisoner's dilemma games and more realistic contexts, such as domestic chores. In the future, we also want to compare the difference between interactions involving only humans and mixed groups including robots.

VI. Conclusion

Our analysis revealed significant differences in participants' cooperative behaviors toward robots depending on group sizes in the interaction, but did not find significant differences in their attitudes. These findings contribute to establishing the importance of studying group effects in HRI and to understanding issues in the design of effective intergroup interaction between humans and robots. Our research also opens up new questions in the study of group effects in HRI, including the relevance of anthropomorphic appearance and interactivity of the robots.

VII. Acknowledgement

We are grateful to all of our participants for their participation, as well as to Matthew Francisco and Brianna Sykes for their advice and assistance with the study, and Indiana University for its support of this research.

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