Is Human-Robot Interaction More Competitive Between Groups Than Between Individuals?

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Abstract—As robots, both individually and in groups, become more prevalent in everyday contexts (e.g., schools, workplaces, educational and caregiving institutions), it is possible that they will be perceived as outgroups, or come into competition for resources with humans. Research indicates that some of the psychological effects of intergroup interaction common in humans translate to human–robot interaction (HRI). In this paper, we examine how intergroup competition, like that among humans, translates to HRI. Specifically, we examined how Number of Humans (1, 3) and Number of Robots (1, 3) affect behavioral competition on dilemma tasks and survey ratings of perceived threat, emotion, and motivation (fear, greed, and outperformance). We also examined the effect of perceived group entitativity (i.e., cohesiveness) on competition motivation. Like in social psychological literature, these results indicate that groups of humans (especially entitative groups) showed more greed-based motivation and competition toward robots than individual humans did. However, we did not find evidence that number of robots had an effect on fear-based motivation or competition against them unless the robot groups were perceived as highly entitative. Our data also show the intriguing finding that participants displayed more fear of and competed slightly more against robots that matched their number. Future research should more deeply examine this novel pattern of results compared to one-on-one HRI and typical group dynamics in social psychology.

Keywords – Robots in society, social robotics, groups of robots, group effects, discontinuity effect, competition, greed, fear, outperformance.

I. INTRODUCTION

Researchers are working to improve human-robot teams for tasks in the army, the police force, search and rescue, medicine, and others (e.g., [1-3]). Having a unified team of humans and robots can increase productivity and success. However, even within teams, conflict can arise between subgroups. For example, humans may compete against robots in their team for resources or out of fear that robots will replace them in the team [4]. When humans are placed in a competing team against robots (e.g., if they perceive themselves to struggle against robots for a job), competition toward robots increases [5].

Research from social psychology documents this type of conflict within and between groups [6-10]. For example, group members who less stereotypically fit the image of the group are often shunned. Human-robot interaction (HRI) literature has also indicated that, even within a cohesive mixed human-robot team, there is division between the humans and robots [5]; human teammates were viewed as more positive and treated better than robot teammates. In more extreme circumstances, when motivation for protecting the human ingroup is stronger, people might sabotage robot “teammates.” Even in a neutral environment in the wild, groups of children (compared to individual children) were more aggressive toward robots [11]. The current study puts humans and robots, both individually and in groups, in a situation where they could choose to cooperate or compete with each other (Figure 1) to examine human motivation for competition against robots.

Figure 1. Beam robot faces off against a participant.
II. BACKGROUND

Social psychological literature indicates that human group-versus-group interaction is more competitive than individual-versus-individual interaction [12, 13]. This change in behavior is called the “discontinuity effect,” in reference to the shift in the nature and strength of negative reactions when more than two people are engaging in a group interaction with other humans. Most studies examine only those two conditions (group-versus-group or individual-versus-individual), but some research also includes individual-versus-group conditions [14]. People experience different emotions and have different motivations for competition depending on numbers and characteristics of their own team (i.e., ingroup) and of the opposing team (i.e., outgroup), as described below.

A. Ingroup number and entitativity increases competition through negative emotions and greed

Social psychological research indicates that when people are in groups, they experience more negative emotions and compete against other humans more than individuals do [14-18]. HRI research on the discontinuity effect has indicated that human groups are also more negative and competitive than humans when competing against robots [19].

In social psychological research, greed motivates competition more for groups than individuals [13, 20, 21]. This is because greedy behavior of a group member can be morally justified as altruism for one’s ingroup, whereas individuals do not have such justification. Additionally, individuals within a group have social support from the group to behave this way [21-24]. HRI research has not yet examined greed motivation in intergroup interaction. This leads us to Hypothesis 1a:

H1a. Groups of Humans will be more negative, greedy, and competitive toward robots than Single Humans as measured by: (1) more negative emotions, and (2) more greed motivation.

Prior social psychological research indicates that ingroup human entitativity moderates motivation for competition and competitive behavior. Entitativity has been defined as how cohesive a group is (e.g., similar appearance, preference, goals, proximity) [25]. The more entitative a group is, the more the group’s behavior aligns with its goal [26, 27]. It follows that in competitive situations, ingroup entitativity increases that group’s competition [12]. HRI research has confirmed that, when interacting with a robot, high-entitative human groups conform more to the group goals than low-entitative human groups [27]. In this study, we expect higher perceived human group entitativity to relate to higher motivation to compete against robots. Because entitativity magnifies group dynamics, we specifically expect perceived ingroup entitativity to relate to greed.

H1b. Higher perceived human ingroup entitativity will increase greed motivation.

B. Outgroup number and entitativity increases competition through perceived threat, anxiety, and fear

Social psychological research also indicates that players experienced more perceived threat from [14], anxious emotions regarding [28, 29], and overall fear from [14] groups than individuals. This leads them to compete more against groups than against individuals [14]. HRI research, however, has not yet conclusively indicated if humans are more competitive against groups of robots than individual robots. One experiment [19] examined this with people interacting with mechanomorphic iRobot Creates and found no significant effects of the number of robots. However, group effects occur in the context of social interactions, and may not occur toward non-humanlike objects. These machinelike robots may not have been perceived as social enough to cue the discontinuity effect. In the current study, we cued perceptions of robot physical anthropomorphism by using human-height Beam telepresence robots (Figure 1), which gazed at participants with a pair of blinking eyes. We also cued perceptions of other anthropomorphic qualities by having participants speak to the robots, the robots verbally introduce themselves, and the robots and participants discuss strategy together throughout the game.

Previous social psychological research indicates that fear is a bigger motivator while interacting against groups than against individuals [13, 20, 21] because people have learned that groups are typically aggressive. The increased fear may motivate the ingroup to behave competitively to combat anticipated competition from the other group [30]. This leads us to Hypothesis 2a:

H2a. Participants will be more fearful of Groups of Robots than Single Robots as measured by: (1) more perceived threat and anxious emotions, and (2) more fear motivation.

Psychological research indicates that perceived outgroup entitativity moderates intergroup competition. The more entitative participants perceive a competing group to be, the more threatening they see it as, and the more they act to protect their own group [31]. Entitative robot groups have been perceived as more threatening than diverse robot groups or individual robots in a competitive context [32]. In this study, we expect higher perceived robot group entitativity to relate to higher motivation to compete against robots. Because entitativity magnifies group dynamics, we specifically expect perceived outgroup entitativity to positively relate to fear, leading to Hypothesis H2b:

H2b. Higher perceived robot (outgroup) entitativity will increase fear motivation.

C. Interacting with a group of robots may induce motivation to outperform them

Besides greed and fear, a third potential motivation is the desire to maximize one’s own outcomes relative to another [13] (from here on referred to as outperformance). This motivation is distinct from greed because it can actually
diminish one's own performance [20]. For example, to outperform an opponent, one might spend less time on their own projects and more time sabotaging another's. Outperformance has not been studied much as a unique motivation in social psychology or HRI [20, 33], but it may have a large influence on HRI. In many HRI cases, mutual cooperation of human-robot groups will lead to optimal rewards [13]. It will be important to HRI to understand if, and under what circumstances, people will sabotage robots even at a cost to themselves.

Studies show that perceived threat from robots (e.g., induced by perceived robot autonomy) can make participants very negative toward robots [34], which may lead to outperformance motivation. Because robot groups (as opposed to individuals) and robot group entitativity should induce perceived threat (as described in the above section), these factors may also increase motivation to outperform the robots. This leads to Hypotheses 3:

H3a. Participants will have more motivation to outperform Groups of Robots than Single Robots.

H3b. Higher perceived robot (outgroup) entitativity will increase outperformance motivation.

D. Studying human competition against robots with dilemma tasks

Given the complexity of social life, when to cooperate and when to compete with others often critically depends on the payoff of such decisions. Competitive behaviors can lead to better outcomes for oneself in some cases, but it might lead to lose-lose situations when the payoff structure changes.

For example, in certain cases, it can benefit the group to compete. This is modeled in the Chicken Game [35] (Table 1a): Teams get the most points if they compete (choose D) and the other team cooperates (choose C), meaning that competition in the situation is primarily motivated by greed. This leads to a new hypothesis; we consider it as an extension of Hypothesis 1 because it suggests the same main effect as in Hypothesis 1:

H1c. Groups of Humans, compared to Single Humans, will compete more in the Chicken Game.

In other cases, a group may seek to outperform their opponents, regardless of what it means for themselves. This is modeled in the Maximum Differences (Max Diff) game [35] (Table 1b). In this game, if both teams cooperate, they both get the same high amount of points. However, if one team competes, but the other team cooperates, it would cause a small loss for the competitive team and a greater loss for the cooperative team. Competition here is not due to greed, because competing will actually decrease one's points. We propose a new tentative hypothesis; we consider it as an extension of Hypothesis 3 because it suggests the same main effect as in Hypothesis 3:

H3c. Participants will compete more in the Max Diff game against Groups of Robots than Single Robots.

Table 1. Example Dilemma Matrixes of Chicken (A) and Max Diff (B). Each team chooses to Cooperate (C) or Compete/Defect (D). Then the red team receives the payoff on the right (red) and blue team on the left (blue).

<table>
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<th>Player</th>
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<td>C</td>
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<td>A. Chicken</td>
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E. Conceptual frame for analysis

Our conceptual model has experimental conditions (number of humans, number of robots) as independent variables, which influence perceived threat, emotions, and motivations, in turn causing levels of competition in the Chicken and Max Diff games. We will report ANOVAs of all variables by experimental condition (H1a, H1c, H2a, H3a, H3c). Additionally, we will report multiple regression analyses examining how the motivation measures predict competitive behavior in the two games. We also examine how perceived human group and robot group entitativity affect motivation and competition. We use linear regression to examine this (H1b, H2b, H3b).

III. METHOD

The purpose of this study is to examine perceived threat, emotions, motivation, and competition during intergroup interaction in HRI. Participants entered the lab, either joined groups of three or were told they would play alone, and then played several rounds of the dilemma game against one or three robots. Their behavior and survey responses were recorded. This method is modified from a previous study of the discontinuity effect [13].

A. Design

Number of Humans (Single Human, Group of Humans) and Number of Robots (Single Robot, Groups of Robots) were manipulated as two between-subjects factors. Thus, we use all four conditions rather than just individual-versus-individual and group-versus-group as in most of the human-human interaction literature [13].

B. Participants

Participants were 142 (65% female, average 21 years old) subjects recruited among introductory level psychology students at Indiana University participating in the study for course credit, or they were recruited through email, university classifieds, and listserv emails, and paid $10. There were approximately 20 groups per condition (i.e., 20 individual participants for Single Humans conditions, and 20 groups of three participants for Groups of Humans conditions).

C. Procedure

Participants entered the lab either individually, or in groups of three. They read and signed the informed consent document in private participant rooms and then went to the Common Room (Figure 2) and were introduced to one or three Beam robots by name. Participants then met in the Red Team Room for the experimenter to describe the procedure.
In the Red Team Room, before each round, participants received a dilemma matrix. Human Groups had 20 seconds to discuss their decision within the group; Single Humans were required to spend the same amount of time contemplating the answer, to control for time spent on deliberating. Participants in the Group of Robots condition were told that the robots were also discussing together in the Blue Team Room. Then one representative of humans and of robots met in the Common Room. They had up to 20 seconds to discuss their group’s decisions with each other and try to convince each other of what to do next, before they returned to Team Rooms. Then they had another 20 seconds to make a final decision, with the majority decision being honored at the end of the time allotted. Then the representative returned to the Common Room where the experimenter collected final decisions from the robot and human teams and announced how many points each team received. This occurred with two practice rounds and six actual trials, lasting about 20 minutes. Each time, the dilemma matrix changed (After practice: Chicken in rounds 1, 3, 5, 6; Max Diff in rounds 2, 4).

To increase incentive, participants were told that for one of the trials (randomly chosen) they would each be paid five cents per point their team earned. Points were between 5 and 60, meaning that participants earned between $.25 and $3.00. A random number generator selected the trial for which participants were paid.

During the task, participants were video recorded in the Common Room and audio recorded in the Red Team Room. After this task, participants individually completed online questionnaires. Then participants were debriefed, given course credit, paid according to their winnings described in the above paragraph, and dismissed.

D. Robot

The Beam robot was used, and an animated pair of occasionally-blinking eyes was displayed on its screen. For the Group of Robots condition, the robots had different colored eyes and different-sounding voices. Throughout the trial, the robots were controlled using the Wizard of Oz (WoZ) method, with the researcher controlling the robot using a pre-determined script and verbal content. The robots spoke primarily using pre-generated content in a text to speech generator based on a script to standardize their responses to participants.

Robots always expressed cooperative intent when meeting the human representative (e.g., “I think we should choose X this round; it is the most fair option”). Their decisions were predetermined (cooperate in practice trials: C, C; mostly cooperate in actual trials: C, C, D, C, D, C). Thus, in some trials the robots expressed cooperative intent but then made a competitive decision. Our paper differs from the previous HRI article [19], in which the robots’ game strategy was tit-for-tat. We chose a fixed strategy because previous research shows that outgroup competition increases participant competition [13]; therefore, we ensured that the robot behavior would stay constant across participants.

E. Measures

The following measures were collected through surveys and behaviorally:

1. Emotions and perceived threat
   ○ Emotions (e.g., “When you think of robots in the future, to what extent do you experience the following?:” “fear,” “happiness”; 14 questions) were rated on a scale from 1 (Not at all) to 7 (Very much) [36].
   ○ Perceived threat of robots was rated on a scale from 1 (Strongly disagree) to 7 (Strongly agree). Items measured social threat (e.g., “in a society with many robots, human life will feel less valuable and more expendable”), physical threat (e.g., “I worry that humans who program robots can’t completely prevent them from harming people”), and general threat (e.g., “Having a robot at work or at home seems like it would be difficult”) [37]. Because these threats were not distinguished in a factor analysis (eigenvalue < 1), we combined these 24 measures in the remainder of this study (Cronbach’s $a = .833$).

2. Motivation for competition
   ○ Survey-based measures were asked regarding motivations from prior research (e.g., [24, 38]) and those identified in this paper on a scale from 1 (Not at all) to 7 (To a great extent).
     ▪ Greed (maximizing own benefit; e.g., “I tried to maximize points for my own side, regardless of what it meant for the other side.”) was measured with three questions (Cronbach’s $a = .779$).
     ▪ Fear (“my decisions were greatly influenced by worry about what move the other side might make.”) was measured with one question.
     ▪ Outperformance (“I tried to score more points than the other side, even if that meant my side would score fewer points than we might have by making a different move”) was measured with one question.
     ▪ Cooperation (“I tried to maximize the total points won by both sides”) was measured with one question.
Behavioral competition was measured with the dilemma games. This was measured at the group level (i.e., it was a group decision, as the condition required, and as in previous literature; [12, 13, 16, 20].

- Percent cooperation on Chicken Game (Greed)
- Percent cooperation on Max Diff Game (Outperformance)

3. Entitativity of groups of humans and groups of robots (e.g., “the group was cohesive”) were rated on a scale from 1 (Not at all) to 9 (Very much) with 15 questions [32], respectively.

4. Demographics were collected (age, gender, ethnicity, level of technical training, prior interaction with robots).

5. Other exploratory measures: attitudes toward robots [36], willingness to interact with the robots [37], fairness and loyalty motivation [24, 38], and perceived anthropomorphism of robots [39, 40] were also measured but were not reported below because the analyses of the first two measures were exploratory and did not yield interesting differences across conditions. The motivation and anthropomorphism measures exceeded the scope and topic of this paper.

IV. RESULTS

Data were analyzed in SPSS 24. One participant was excluded due to technical difficulties during the experiment. One participant was excluded because the participant told the robot that they should both choose the answer that would give them both fewer points during the round the robot was supposed to compete with participants (by choosing the option for fewer points). Because the robot seemed to cooperate on this round, it could not be seen as competition, and this participant was excluded. In the end, there were a total of 105 participants: Single Humans-Single Robots (N = 24), Single Humans-Groups of Robots (N = 21), Groups of Humans-Single Robots (N = 51), Groups of Humans-Groups of Robots (N = 57).

Analyses were typically 2 (Number of Humans: Single Humans, Groups of Humans) x 2 (Number of Robots: Single Robots, Groups of Robots) ANOVAs. P values of less than .05 were considered significant. All analyses occurred on an individual level unless otherwise stated.

A. Perceived threat from and emotion toward robots (H1a, H2a, H3a)

Overall perceived threat was affected by the interaction between Number of Humans and of Robots (F(1, 149) = 8.02, p = .005, η² = .051) such that Single Humans felt more threat from Single than Groups of Robots, but Groups of Humans felt more threat from Groups of than Single Robots (Figure 3).

For emotions, we ran a factor analysis (Figure 4), and three factors emerged, like in previous research (e.g., [37]): Positive (respect, happiness, gratefulness, excitement, sympathy, a = .783), Negative (disgust, anger, sadness, pity, guilt, a = .780), Anxious (fear, anxious, resentment, uneasiness, a = .775). We ran a 2 x 2 ANOVA on each emotion (Figure 3).

Positive emotions showed no significant effects.

Negative emotions had an effect of Number of Humans (F(1, 149) = 4.98, p = .027, η² = .032) such that Groups of Humans reported more negative emotions than Single Humans.

Anxious emotions had an interaction effect (F(1, 149) = 5.54, p = .020, η² = .036) such that Single Humans felt more anxious toward Single than Groups of Robots (Figure 3), but Groups of Humans felt more anxious toward Groups of Robots than toward Single Robots.

B. Motivation for interaction

1. Dilemma game (H1c, H3c)

We performed a 2 (Number of Humans: Single, Group) x 2 (Number of Robots: Single, Group) x 2 (Game Type: Chicken, Max Diff) mixed ANOVA (Figure 5). Participants displayed less competitive behavior in Max Diff than in the Chicken games (F(1, 74) = 71.28 , p < .001, η² = .491). There was a marginal effect of Number of Humans (F(1, 74)
Groups competed more than Individuals. A marginal interaction effect between Number of Humans and Number of Robots ($F(1, 74) = 3.16, p = .079, n^2_p = .041$) indicated that for Single Robots, Number of Humans had no effect, but for Robot Groups, Groups of Humans competed more than Single Humans.

$3.51, p = .065, n^2_p = .045$ such that Groups competed more than Individuals. A marginal interaction effect between Number of Humans and Number of Robots ($F(1, 74) = 3.16, p = .079, n^2_p = .041$) indicated that for Single Robots, Number of Humans had no effect, but for Robot Groups, Groups of Humans competed more than Single Humans.

2. Measures of motivation (H1a, H2a, H3a)

First, we examined the relationship between survey and behavioral measures for greed and outperformance to understand how survey measures relate to behavioral measures of motivation in the dilemma games. To this end, we constructed two multiple linear regression models with four survey-based motivation measures as predictors and competitive behavior in either the Chicken game or the Max Diff game as the outcome variable.

As expected, greed motivation, as measured by our survey, was a strong predictor of competitive behavior in the Chicken game ($B = .038, p = .006$). Outperformance motivation also positively predicted competitive behavior ($B = .025, p = .008$), cooperation motivation negatively predicted it ($B = -.054, p < .001$).

As expected, outperformance motivation, as measured by our survey, was a strong predictor of competitive behavior on the Max Diff game ($B = .048, p = .001$). Cooperation motivation also negatively predicted competition ($B = -.065, p < .001$).

Next, we ran a series of 2 (Number of Humans) x 2 (Number of Robots) ANOVAs on each motivation.

Greed displayed an interaction effect ($F(1, 149) = 8.55, p = .004, n^2_p = .054$) such that Single Humans were more motivated by greed when competing against Single than Groups of Robots. Conversely, Groups of Humans were more motivated by Greed when interacting with Groups of than Single Robots (Figure 6).

Fear displayed a marginally significant main effect ($F(1, 149) = 3.15, p = .078, n^2_p = .021$) such that humans had slightly more fear toward Groups of than Single Robots.

Motivations of outperformance were not affected by condition.

Cooperation displayed a main effect ($F(1, 149) = 5.11, p = .025, n^2_p = .033$) such that Groups of Humans were less motivated to cooperate than Single Humans.

Figure 5. Ratio of time that groups competed with the robots depending on if the situation was Chicken (related to greed) or Max Diff (related to outperformance). Error bars denote standard error.

C. Entitativity of groups (H1b, H2b, H3b)

Ingroup entitativity ($a = .824$) was indicated by linear regression to marginally correlate positively with competitive behavior on the Chicken game ($F(1, 104) = 3.59, p = .061, B = .040$) and survey ratings of motivations of greed ($F(1, 104) = 2.88, p = .093, B = .197$). It did not correlate with competitive behavior on the Max Diff game or fear from the robots.

Outgroup entitativity ($a = .874$) was indicated by linear regression to marginally positively relate to rating motivations based more on fear ($F(1, 75) = 3.08, p = .083, B = .275$), but not to any other motivations or competitive behavior.

V. DISCUSSION

In this study, we examined participant perceived threat, emotions, motivation (greed, fear, and outperformance), and competition during intergroup interaction with robots. Overall, in dilemma games, participants competed (rather than cooperated) against the robots more than half of the time. In particular, they competed more in the Chicken game (related to greed motivation), than in the Max Diff game (related to outperformance motivation). This indicates that in this study, the motivation to get more points outweighed the desire to win by the most points.

A. Studying motivation behind human competition with robots on dilemma tasks

Our research suggests the viability of studying human-robot competition using dilemma tasks. As theorized in previous literature, the Chicken game was closely positively related to survey reports of greed motivation, but it also related to outperformance motivation. The Max Diff game positively related to survey reports of motivation for
outperformance, but not to greed. This indicates that these motivations for competition with robots are conceptually distinct from each other.

B. Competition against robots produced a surprising interaction effect such that participants were more competitive against the same number of robots (not hypothesized)

We examined competition based on the number of humans and number of robots. The overall findings indicated a different pattern of discontinuity effects during competition against robots compared to the previous literature on humans. Studies with humans show that individual-individual interaction is the least competitive, individual-group and group-individual conditions are moderate, and group-group is the most competitive [18]. In contrast, in HRI we found that individual-individual and group-group interaction are both more negative and competitive than individual-group and group-individual. This interaction effect occurred across measures of perceived threat, anxious emotion, survey-based greed motivation, and competitive behaviors in the dilemma games. This pattern demonstrates that greed-motivated behavior does not simply increase when participants are in groups (compared to individual), and that fear-motivated behavior does not simply increase when opponent robots are in groups (compared to individual). Thus, the interaction effect demands a different kind of explanation than the traditional motivation of fear or greed.

Given the consistent yet unexpected interaction patterns, we can only speculate why they may have occurred: It may be that participants viewed competition against nonhumans as more serious and combative when against a group that was the same size as their own group, rather than a different size, which in turn increased competition motivation and behaviors. However, before speculating extensively, this effect should be replicated.

C. Groups of humans increased negative emotions and competition (H1a partially supported and H1c supported)

Our hypothesis that groups of humans would be more competitive than single humans was generally supported. We found that groups had more negative emotions, competed marginally more on the Chicken game, and showed marginally less survey-measured cooperation motivation. There was no significant effect on survey ratings of greed. Competition on the Chicken game positively related to survey ratings of greed motivation. The findings in this study of marginal significance on the Chicken game, but not on survey ratings of greed may indicate that participants were not consciously aware of their greed-based motivations or not willing to state them explicitly, despite that they acted based on them.

The results support previous findings that human groups, compared to human individuals, are more competitive toward robots [19]. The relationship parallels findings in human-human interaction, which repeatedly showed that human groups were more greedy and competitive than were human individuals [14, 16, 20].

D. Human group entitativity increased competition (H1b supported)

Overall, participants who perceived higher ingroup entitativity displayed more greed-based competitive behavior and more survey ratings of motivation by greed. This supports H1b and vast amounts of literature in social psychology [12, 20, 21, 25]. This study makes the novel contribution that the competitiveness inspired by ingroup entitativity occurs not only with interactions with other humans, but extends to HRI. Thus, when introducing robots in a situation that humans perceive as potentially competitive (e.g., the workplace), it may be useful to reduce perceptions of human group entitativity and thereby reduce greed-based competition with robots.

E. Groups of robots did not increase fear (H2a and H2c failed to support)

Our hypothesis that people would be more fearful of groups of robots than single robots was not supported. There was no main effect on perceived threat or anxious emotions, and only a marginal effect in the expected direction on fear motivation. It may be that fear was not a major influence because participants did not view the situation in loss-based terms. That is, in this study participants would gain some money based on the results of the dilemma games. Prior research indicates that people process losses differently than they process gains [41, 42]. If the study were run again with participants automatically receiving a certain amount of money, then losing some money based on the results of the dilemma games, the effects of fear may have been stronger. Future studies should examine competitive interaction with groups of versus single robots when participants have more to lose.

F. Robot group entitativity increased fear (H2b supported)

Higher perceived robot group entitativity marginally increased fear motivations in this study. This aligns with prior literature that more entitative outgroups are more feared [12, 31, 32]. This also supports research indicating that robot group entitativity can account for negative responses to groups of robots [43, 44]. Again, effects of fear might have been stronger if participants had been told they might lose something based on the results of the games. Applied to HRI, designers may wish to create more diverse groups of robots (e.g., in appearance, behavior) to reduce perceived robot group entitativity and thereby reduce fear of robot groups.

G. Interacting with robot groups (rather than individuals) did not induce motivation to outperform them (H3a-c not supported)

In this study we explored outperformance motivation in HRI. There was no effect of number of robots on survey ratings of outperformance motivation or competition on the Max Diff game. Perceived robot group entitativity did not
affect outperformance motivation. This, in addition to the finding that participants competed less on Max Diff than Chicken games, suggests that people are more likely to cooperate when outperforming robots is their only reward of competing. Because human-robot teams may accomplish the most during mutual cooperation, this is good news for HRI. Future research might focus on fear and greed, rather than outperformance, motivation for competition.

H. Limitations and future studies

This study involved interaction with one or more robots in a situation that is a vast simplification of the real world. While this allowed the researchers to observe actual human behavior with high internal reliability, future studies should also examine how participants would respond in real world situations to increase external reliability. For example, they might examine perceived threat, emotion, motivation, and competition when interacting with a robot on a specific work-related job. This research should also be examined during long-term interaction to determine the lasting effects of competition motivation.

We performed this study only with people competing against robots, and not against humans. However, the study from social psychology on which we based this research [13], and others (e.g., [12, 20, 21, 25]), revealed stable enough results that we conclude it is reasonable to compare against the typical effects in humans.

We used a smaller sample size (20, rather than 30 groups per condition) compared to previous studies that found the effects in humans (e.g., [16]), and may have found stronger effects if we had used a larger sample size.

The procedure of the study involved a game that is typically meant to encourage competition (i.e., dilemma games) to examine behavior and motivation that leads to competition. Prior research indicates that groups would have been even more competitive than individuals if they had performed only one trial went rather than multiple trials of the dilemma game [33]. If we had done this, effect sizes may have been larger.

Although we used the dilemma games that roughly corresponded to measure greed- and outperformance-motivated competition, we did not use dilemma games that corresponded to fear-motivated competition. Fear may differentially affect behavior toward robot individuals versus groups, especially in loss-based situations. Future experiments should examine this behavioral measure of fear in human-robot competition.

VI. CONCLUSION

Overall, the study examined if variation in numbers from human groups and competing robot groups parallels group dynamics in human-human interaction. One or three participants interacted with one or three robots on a series of dilemma games chosen to provoke competition. Results indicate overall similarities to human-human interaction and reveal novel differences.

1. Our novel findings indicate that perceived threat, anxious emotion, greed motivation, and competition increased when humans interacted with robots of the same number as the humans’ group (1 or 3).
2. Like in social psychology, compared to single humans, groups of humans, and especially entitative groups, were more negative and competitive toward robots.
3. Unlike in social psychology, groups of robots did not increase fear and competition unless they were perceived as entitative.

The illumination of how intergroup interaction differs compared to one-on-one interaction in HRI calls for more intergroup interaction research. The novel differences between human-human and human-robot interaction in group situations calls for more research to clarify differences in intergroup interaction. These and future findings will provide practitioners with strong recommendations for how to decrease human-robot competition in different contexts, such as the workplace, and increase effective, efficient human-robot collaboration.

VII. ACKNOWLEDGMENTS

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VIII. REFERENCES


