Robble of Robots Effects: Number and Type of Robots Modulates Attitudes, Emotions, and Stereotypes
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ABSTRACT
Robots are expected to become present in society in increasing numbers, yet few studies in human-robot interaction (HRI) go beyond one-to-one interaction to examine how emotions, attitudes, and stereotypes expressed toward groups of robots differ from those expressed toward individuals. Research from social psychology indicates that people interact differently with individuals than with groups. We therefore hypothesize that group effects might similarly occur when people face multiple robots. Further, group effects might vary for robots of different types. In this exploratory study, we used videos to expose participants in a between-subjects experiment to robots varying in Number (Single or Group) and Type (anthropomorphic, zoomorphic, or mechanomorphic). We then measured participants’ general attitudes, emotions, and stereotypes toward robots with a combination of measures from HRI (e.g., Godspeed Questionnaire, NARS) and social psychology (e.g., Big Five, Social Threat, Emotions). Results suggest that Number and Type of observed robots had an interaction effect on responses toward robots in general, leading to more positive responses for groups for some robot types, but more negative responses for others.

Categories and Subject Descriptors

General Terms
Experimentation, Human Factors.

Keywords
Human-robot interaction, inter-group interactions, group effects, robot type, emotion, attitudes, stereotypes.

1. INTRODUCTION
Contemporary visions of how robots will be used in daily life include many situations in which people interact and share their space with not only one, but multiple, robots. Gates’ vision of “robots in every home” includes a Roomba, a laundry-folding robot, and a mobile assistive robot within the home, with security and lawn-mowing robots outside [1]. Field studies of robots in educational facilities have used multiple Qrio humanoids along with the Rubi platform [2]. Eldercare institutions already employ multiple seal-like PARO robots simultaneously. Researchers also suggest various uses for robotic swarms, such as modular robots that self-configure into different types of furniture [3], small robotic vacuums that work together to reach hard-to-clean areas [4], and robots that can help in dangerous situations. Researchers and funders alike expect that humans and robots will be able to “symbiotically coexist” and collaborate [5], but there is little research on human interaction with groups of robots to guide the development of socially acceptable multi-robot applications.

While many future application ideas imply the use of multiple robots interacting with people and with each other, most previous human-robot interaction (HRI) research only involves single robots, even when examining effects like a robot’s group identity (e.g., as German; [6]). Many important social psychological factors that determine the quality and quantity of social interactions have been successfully applied to HRI research (e.g., gaze [7, 8]). Less frequently applied, however, are social psychological theories that predict changes in these social factors when exposed to or interacting with groups versus individuals [9, 10]. In this study, we tested whether effects parallel to those found in interactions among humans may be found in HRI—specifically, that one’s attitudes, emotions, and stereotypes of robots may significantly differ when observing or interacting with an individual robot versus a group of robots.

In addition, we extend existing HRI research (e.g., [8, 11-13]) on the importance of robotic type (manipulated by robots’ physical appearance and behavior) to examine its effects in individual versus group contexts. Most studies in HRI that examine group effects in robots use humanoid robots only (e.g., [6]). Previous studies suggest that the level of anthropomorphism of a robot type may influence social qualities applied to it, which moderate how socially people behave toward robots [8]. In addition, preliminary evidence from recent studies suggests that non-anthropomorphic form may lower group effects [9, 10]. However, these researchers have yet to follow up about the specifics of these effects.

To investigate the extent to which attitudes, emotions, and stereotypes towards robots in general are modulated by observing single vs. multiple robots of various types, we showed participants videos involving one or several robots and varied robot type (anthropomorphic, zoomorphic, mechanomorphic). After this, we administered questionnaires to measure a wide range of perceptions and reactions to robots. Measures were drawn from literature on both human-robot and human-human interaction.

2. BACKGROUND AND RELATED WORK
HRI researchers have successfully adopted social psychological methods and theories to HRI—in particular, when measuring perceptions of individual robots. Attitudinal and behavioral responses to robots are often similar to responses to other humans in human-human interaction (HHI), as seen in the computer-as-social-
actors paradigm [14]. For example, research suggests that humans attribute human-like capabilities, such as theory of mind and free will, to certain robots, but not others [15]. Humans even respond differently to robots that are defined as ingroup versus outgroup members, exhibiting varying behaviors and attitudes towards the same robot, depending on the robot’s arbitrarily assigned social membership (e.g., German vs. Egyptian) [16, 17]. In this paper, we extend the HRI literature by a) examining the effect of exposure to groups of robots, b) evaluating how group effects are displayed in relation to robots of different types (physical forms and behaviors), and c) drawing on conceptualizations and measures from social psychological research on intergroup interaction (for example, measures of various types of threat and emotion).

### 2.1 Robot Number and Group Effects

The hypothesis that robot number can alter social perception is based on previous research in social psychology that indicates significant variation in the social perception of individuals versus groups [18]. Intergroup interactions among humans are generally more negative, uncooperative, and even aggressive than interactions between individuals. Researchers have found that, when two teams of three players or two individuals participate in “games” where they have to allocate valuable points between themselves and the opponent, teams like the opponents less and make more competitive choices compared to individual players [19]. Similarly, teams (compared to individuals) are more likely to retaliate by harming the opponents when the opponent takes an initial action perceived as aggressive [20].

Even in non-competitive contexts, the presence of groups can have negative consequences on social perceptions: how humans think about, feel, and react to robots. In many social situations, individuals ‘automatically’ (e.g., without conscious awareness) categorize others according to easily available social category cues, such as gender and race, often leading to greater encoding and recollection of behaviors that are stereotypic of members in that category [21]. Social categorization frequently causes negative social perceptions of other groups because in the social categorization process (e.g., coding “us” versus “them”), individuals often recall more negative information for the other than for their own group, leading to increased antipathy [22].

Regarding robots, negative group effects may be exacerbated by at least three factors: unfamiliarity with robots, robots’ physical similarity, and current stereotypes about robots. First, unfamiliarity with an outgroup increases susceptibility to using stereotypes [23], and most people have little to no experience with robots. Second, similarities in physical appearance can lead to increased group effects, such as perceived threat [24]. Finally, in the US in particular, many popular and media-related stereotypes of robots are negative [25]. Despite the potential for negative attitudes, emotions, and stereotypes toward groups of robots to arise when group context is salient, little research explored the influence of such group effects on social perceptions of robots.

However, robots in groups may also be viewed positively. One hypothesis is that interacting with multiple robots causes people to self-categorize as humans, which focuses them on the distinction between humans and robots. While that might result in most robot types (e.g., mechanomorphic, zoomorphic) being seen as more different from humans and perceived more negatively, human-like type (e.g., NAO) may be perceived more positively. Second, certain positive qualities of robots may only be revealed in group settings. For example, robots may appear more social (e.g. becoming more ‘friend-like’) when seen interacting with other robots. Third, seeing multiple robots could increase perception of robot value, usefulness, etc. (for example, seeing swarms of fire-fighting robots versus a single robot).

Previous research on the ‘discontinuity effect’ found that groups of various sizes (two to eight members) show similar patterns of interaction, with both group and non-group members [26]. For the Group conditions in this study, we used two to three robots as numbers that would contrast with the single-robot conditions.

### 2.2 Robot Type and Social Perceptions

Several lines of HRI research suggest that a robot’s type (physical form and behavior) influences social perceptions. The ‘uncanny valley’ [27] is a classic example of non-linear change in attitudes toward robots depending on how human-like they appear. Recent research also suggests that motion, related to type, influences social perception—for example, by changing the subjective feeling of social ‘ease’ when interacting with the robot [28].

Tasks and behavior have been shown to affect what form people expect the robot to have, and vice versa [29]. Form also largely determines a robot’s social behavioral repertoire (e.g., gaze and gestures enhance social interaction) [13], and thus can influence expectations for social interactions. Anthropomorphic features can confer social advantages to robots by allowing them to engage in human-like social behaviors, such as emotional expressions [13], which can enhance social trust and other perceptions [8].

### 2.3 Interaction: Robot Number and Type

The effects of number and type have been treated separately in human-human and human-robot interaction. The interaction between these two variables—for example, how type may determine the effects of number—has seldom been explored.

In most HRI research examining group effects, the robots used are anthropomorphic (e.g., Flobi, Robovie). In order to create a more social context, these experiments often introduce the robots as fitting into existing human social categories (e.g., “this robot is German”) or by creating shared goals between robot and participant [10, 16]. In other studies, the experimenter treats the robot as human-like and the robot engages in various social behaviors (e.g., didactic teaching, complimenting shoes) [15].

We focus on two unexplored areas in this study. First, many robots in the near future will not be human-like, as they will be designed to perform specific behaviors and functions, and robot type will likely alter the effects of group context on social perception. Although some studies have found group effects in HRI similar to in HHI (e.g., [16]), studies involving non-anthropomorphic robots have shown notable differences [9, 10]. In one study, competition against mechanomorphic iCreate robots increased when participating in a group scenario compared to one-on-one interaction, but implicit (IAT) and explicit (NARS) attitudes toward robots did not change. In contrast, in studies of group competition in humans and humanoid robots, explicit attitudes also tend to become more negative [9]. It seems, therefore, that the extent of a robot’s anthropomorphism may influence group effects on social perception.

Second, few studies have explored responses to multiple robots that are simultaneously present and interacting with each other. Many factors known to modulate social perception toward others, such as degree of similarity between conspecifics, ingroup entitativity (e.g., how similar they are with each other), emotion sharing, and empathy, are likely to only be perceptible when observing individuals interacting with others within their group. Some of these factors may strongly influence social perception, but most HRI studies do not show robots interacting with other robots. As previously discussed, the physical form of robots can
also restrict their social behavioral repertoire, which includes potentially important group-based behaviors. Some of these social behaviors may be more observable in anthropomorphic robots, leading to different group effects across types of robots [13].

<table>
<thead>
<tr>
<th>Mechanomorphic</th>
<th>Zooomorphic</th>
<th>Anthropomorphic</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Mechanomorphic]</td>
<td>![Zooomorphic]</td>
<td>![Anthropomorphic]</td>
</tr>
</tbody>
</table>

Figure 1: Robots for Type condition manipulation

2.4 Overview

In social psychology, group interaction and observation alters perceptions of others [18]. In this study, we expect the presence of a group, rather than individual, robots, to affect how participants view robots in general. However, robots vary in type, and research has not yet systematically examined how robot type might influence the effects of group presence. In this exploratory study, we examine the effects of number, type, and the number by type interaction on attitudes, emotions, and stereotypes held toward robots, which will be critical to the design and application of robots for everyday use. We manipulated what video participants watched to prime their ideas of robots, and then administered questions about robots in general to explore the effect of Number and Type of an exemplar robot on general perceptions of robots.

3. METHODS

3.1 Study Design

The study had a 2x3 between-subjects design. Participants watched a video of robots. In the video, Number (Single, Group) and Type (NAO (anthropomorphic), Pleo (zoomorphic), iCreate (mechanomorphic); Figure 1) design was manipulated. Videos in Group conditions showed two NAOs, three Pleos, or three iCreates, NAOs performed anthropomorphic behaviors (e.g., standing, waving), Pleos performed zoomorphic behaviors (e.g., “eating,” walking), and i Creates performed mechanomorphic behaviors (e.g., driving, beeping). Robots performed similar behaviors in single and group videos. In Group conditions, the robots often performed coordinated behaviors (e.g., walking).

3.2 Measures

Most HRI studies involve robot-specific measures (e.g., Godspeed Scale, Ezer Analogies, NARS), and occasionally some measures from HHI (e.g., Big 5). We chose to use a range of measures from HRI, as well as a range of measures from social psychology that have been used to examine stereotypes and prejudice in studies of interaction between groups. This allowed us to examine social perceptions of robots typically not explored in HRI: attitudes (general thoughts; e.g., I don’t like robots), emotions (e.g., I fear robots), and stereotypes (beliefs about a group; e.g., robots will work in factories) [30]. Below are the measures by category:

**Attitudes:**
- Negative Attitudes toward Robots Scale (Subscales: S1-Situation of Interaction, S2-Social Influence of the Robots, S3-Emotion in Robots During Interactions) [31]
- Direct measure of attitude toward robots (e.g., “I like robots,” “I feel positive toward robots”)

**Emotions:**
- Emotion items (e.g., “I fear robots;” “I respect robots”) [32]
- Threat appraisal items (e.g., “Robots threaten people’s jobs.” Subscales: social, physical, economy, general)

**Stereotypes:**
- Big 5 personality items, modified so participants rated robots’ traits (subcales: Conscientiousness, Extroversion, Agreeableness, Openness to Experience, Neuroticism) [33]
- Godspeed Questionnaire (subcales: Anthropomorphism, Animacy, Likeability, Perceived Intelligence, Perceived Safety) [34]
- Ezer analogy items (e.g., robots “in the near future” will be “like a pet,” “like a toy”) [35]
- Robot work contexts (e.g., “I think robots should work in classrooms”)
- Situational appraisals of robots (e.g., “I would trust a robot to invest some of my money in the stock market”)

Demographics (age, gender, field of study, technological experience) were also recorded.

3.3 Procedure

The study took place in the Indiana University R-House Lab. College-aged participants were tested individually. After they completed the informed consent, participants watched one of six two-minute robot videos (iCreate, Pleo, NAO – as a single robot or group of two or three robots). After the video, participants completed the measures listed above, in reference to robots in general rather than the specific robots they viewed. This was to ascertain how exposure to a particular type of robot would affect overall perceptions of robots. Measures were presented in a standard order, arranged in an attempt to minimize carry-over effects from one scale to the next. Then, participants were debriefed and compensated with $10 or course credit.

4. RESULTS

For comparisons among conditions, 2 (Single, Group) x 3 (NAO, Pleo, iCreate) ANOVAs were performed in SPSS. *p*-values of .05 or less were considered statistically significant. For each subsection below, if a Number or Type main effect or a Number x Type interaction was found, it is reported. F and *p* values for main effects of Number and Type and interactions are found in the tables along with means and standard deviations.

Post-hoc analyses were performed in R, with the Tukey Test used to compare main effects, and uncorrected *p*-values are reported for interaction effects. These differences and *p*-values are reported within the text (not tables). Other analyses were excluded from this paper due to space limitations.

4.1 Participants

127 participants were recruited at Indiana University (See Table 1 for details across conditions).

<table>
<thead>
<tr>
<th>Table 1: Participant Demographics</th>
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<tbody>
<tr>
<td><strong>Demographics</strong></td>
</tr>
<tr>
<td><strong>Age (yr)</strong></td>
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<tr>
<td><strong>Sex (%)</strong></td>
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<tr>
<td><strong>N (%)</strong></td>
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<tr>
<td><strong>CS (%)</strong></td>
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<tr>
<td><strong>Study (%)</strong></td>
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<tr>
<td><strong>Science (%)</strong></td>
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<tr>
<td><strong>Undecided (%)</strong></td>
</tr>
</tbody>
</table>
4.2 Number and Type Results

4.2.1 Attitudes (Table 2)

**NARS.** Participants rated items from 1 (Strongly Disagree) to 5 (Strongly Agree) about negativity toward robots. Ratings tended to be higher (i.e. more negative) for Group than Single iCreate conditions, but lower for Group than Single NAO conditions.

**S1: Situation of Interaction.** No main effects (Number or Type) occurred, but a significant interaction of Number and Type (\(p < .01\)), indicated that Group iCreates induced significantly higher (more negative) S1 scores than Single iCreates (\(p < .01\)), while NAOs showed the opposite effect (\(p = .05\)).

**S2: Social Influence of Robots.** A main effect for Type (\(p < .001\)) was found, such that Pleos elicited lower scores (i.e. less negative) than NAOs (\(p < .05\)) and iCreates (\(p < .01\)). A Number x Type interaction was found (\(p < .01\)), with iCreates inducing higher (i.e. more negative) scores in Single than Group conditions (\(p < .01\)) and NAOs inducing lower scores in Single than Group (\(p = .05\)).

**S3: Emotion in Robots During Interactions.** No significant differences were found.

**Direct attitude measure (liking, feeling positive toward robots):** Number x Type interactions were found (all \(p < .05\)), such that participants in Group NAO rated robots more positively than Single NAO for Liking, Positivity, and Disliking, while the reverse effect occurred for iCreates, with these scores lower for Group iCreates, compared to Single iCreates (all \(p < .05\)).

**Emotions (Table 3)**

**Emotions.** Participants rated items from 1 (Strongly Disagree) to 5 (Strongly Agree). Higher ratings for negative emotion items (e.g., fear, anxious) tended to be found for Groups than Single iCreate, while the opposite trend emerged for NAOs (negative emotions were lower for Group than Single NAO conditions).

**Anxiety/Fear/Distrust/Security/Uneasiness:** A Number x Type interaction was found for numerous items (all \(p < .05\)), such that Group iCreates induced higher ratings of distrust, uneasiness, anxiety, fear, and lower security (all \(p < .01\)) than Single iCreate. An opposite trend emerged for NAOs, with Group NAOs eliciting lower ratings of uneasiness and fear (ps < .05) than Single NAOs.

**Usefulness:** A Number x Type interaction was found (\(p < .05\)), such that Group iCreates elicited lower ratings (\(p < .05\)) compared to Single iCreates, while group NAOs elicited higher, yet nonsignificant usefulness ratings compared to single NAOs.

**Pity:** A main effect of Type was found, with Pleos eliciting more pity than iCreates (\(p = .05\)). No interaction effects were found.

**Gratefulness:** A Number x Type interaction was found (\(p < .05\)), such that Group NAOs elicited higher scores than Single NAOs (\(p < .01\)), but for iCreates and Pleos number did not matter.

Other emotion items not mentioned (excited, useless, sympathy, pride in humanity, sad, superior, inferior, happy, respect, resent, guilt, envy, disgust) showed no significant differences.

**Threat.** Participants rated items from 1 (Strongly Disagree) to 5 (Strongly Agree) regarding robot threats. Overall, Group iCreates tended to elicit higher ratings (i.e., more perceived threat) than Single iCreates, while the opposite trend occurred for NAOs.

No main effects were detected, but a Number x Type interaction for Social Threat was found (\(p < .001\)), such that higher Social Threat ratings occurred for Group than Single iCreates (\(p < .05\)), while NAO and Pleos exhibited non-significant decreases in Social Threat scores from Single to Group. There were no significant differences across conditions for General Threat, Economic Threat, or Physical Threat.

4.2.2 Stereotypes (Table 4)

**Big Five.** Participants rated traits from 1 (Strongly Disagree) to 7 (Strongly Agree). For Agreeableness, a main effect of Type was found, with Pleo conditions eliciting higher ratings of robots “in general” than participants in the NAO conditions (\(p < .05\)). No other significant differences between conditions were observed. No other Big 5 trait elicited significant differences.

**Godspeed.** Participants rated robot traits using a ‘semantic differential’ response format (e.g., for Fake-Natural: from 1- Fake to 5- Natural). For the Likeability Subscale, a main effect of Number occurred, with Groups rated higher than Singles (\(p < .05\)). No other significant differences between conditions were observed. For the Likeability or other subscales.

**Ezer Analogies.** Participants rated analogies for ‘what you imagine robots in the near future might be like’ from 1 (Not at all) to 5 (To a great extent). Specific analogies are listed below.

**Friend:** A main effect of Type was found, with Pleos rated higher than iCreates (\(p = .05\)). A Number x Type interaction was found (\(p < .01\)), with Group Pleos rated lower than Single Pleos (\(p = .01\)), but Group iCreates higher than Single iCreates (\(p < .05\)).

**Servant:** A main effect of Type was found. NAOs induced higher ratings than Pleos (\(p < .05\)). Number and Type interacted (\(p < .05\)) with lower ratings for Group than Single Pleos (\(p < .05\)), but nonsignificantly higher ratings of Group than Single robots for NAO and iCreate conditions. No differences were found for Appliance, Assistant, Human, Machine, Pet, Teammate, or Toy.

**Table 2. Attitudes: NARS, Like/Dislike**

<table>
<thead>
<tr>
<th>Attitudes</th>
<th>NAO M(SD)</th>
<th>Pleo M(SD)</th>
<th>iCreate M(SD)</th>
<th>Statistical Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NARS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>Single 2.41(70)</td>
<td>1.96(36)</td>
<td>1.97(52)</td>
<td>(F) 1.076, 1.858</td>
</tr>
<tr>
<td></td>
<td>Group 2.03(61)</td>
<td>2.08(63)</td>
<td>2.56(76)</td>
<td>(n^2) 0.099</td>
</tr>
<tr>
<td>S2</td>
<td>Single 3.28(54)</td>
<td>2.97(70)</td>
<td>2.93(62)</td>
<td>(F) 0.144, 5.128**</td>
</tr>
<tr>
<td></td>
<td>Group 3.08(52)</td>
<td>2.66(77)</td>
<td>3.57(79)</td>
<td>(n^2) 0.078</td>
</tr>
<tr>
<td><strong>Emotion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Like</td>
<td>Single 3.5(100)</td>
<td>4.1(0.64)</td>
<td>4.1(0.69)</td>
<td>(F) 0.02, 0.83</td>
</tr>
<tr>
<td></td>
<td>Group 4.4(078)</td>
<td>3.9(104)</td>
<td>3.5(101)</td>
<td>(n^2) 0.06</td>
</tr>
<tr>
<td>Positive</td>
<td>Single 3.7(092)</td>
<td>4.1(0.69)</td>
<td>4.1(0.76)</td>
<td>(F) 0.26, 0.19</td>
</tr>
<tr>
<td></td>
<td>Group 4.3(071)</td>
<td>3.9(97)</td>
<td>3.8(092)</td>
<td>(n^2) 0.06</td>
</tr>
<tr>
<td>Dislike</td>
<td>Single 2.2(101)</td>
<td>1.8(0.64)</td>
<td>1.9(0.72)</td>
<td>(F) 0.00, 1.37</td>
</tr>
<tr>
<td></td>
<td>Group 1.7(070)</td>
<td>1.9(0.77)</td>
<td>2.3(104)</td>
<td>(n^2) 0.05</td>
</tr>
</tbody>
</table>

\* signifies that \(p < .05\), ** signifies that \(p < .01\)
Table 3. Emotions: Emotion and Threat

<table>
<thead>
<tr>
<th>Emotion</th>
<th>NAO M(SD)</th>
<th>Pleo M(SD)</th>
<th>iCreate M(SD)</th>
<th>Num F(1,121)</th>
<th>Type F(2,121)</th>
<th>M(SD)</th>
<th>Type F(2,121)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Useful</td>
<td>Single 4.3(0.72)</td>
<td>Group 4.6(0.51)</td>
<td>Group 4.6(0.51)</td>
<td>4.7(0.47)</td>
<td>F 0.09</td>
<td>0.15</td>
<td>3.27*</td>
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<td>Distrust</td>
<td>Single 2.4(1.05)</td>
<td>Group 2.1(0.97)</td>
<td>Group 2.1(0.97)</td>
<td>2.3(0.10)</td>
<td>F 0.08</td>
<td>0.28</td>
<td>5.61*</td>
</tr>
<tr>
<td>Uneasy</td>
<td>Single 2.7(0.92)</td>
<td>Group 2.3(0.91)</td>
<td>Group 2.3(0.91)</td>
<td>2.7(0.89)</td>
<td>F 0.50</td>
<td>0.24</td>
<td>7.55**</td>
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<tr>
<td>Anxious</td>
<td>Single 2.5(0.89)</td>
<td>Group 2.0(0.88)</td>
<td>Group 2.0(0.88)</td>
<td>2.4(1.04)</td>
<td>F 3.37</td>
<td>0.70</td>
<td>7.62**</td>
</tr>
<tr>
<td>Fear</td>
<td>Single 2.8(1.16)</td>
<td>Group 1.9(1.08)</td>
<td>Group 1.9(1.08)</td>
<td>2.0(0.86)</td>
<td>F 0.95</td>
<td>0.36</td>
<td>8.97**</td>
</tr>
<tr>
<td>Grateful</td>
<td>Single 3.0(0.83)</td>
<td>Group 3.8(0.85)</td>
<td>Group 3.8(0.85)</td>
<td>3.7(0.67)</td>
<td>F 0.90</td>
<td>1.00</td>
<td>4.20*</td>
</tr>
<tr>
<td>Secure</td>
<td>Single 2.7(0.79)</td>
<td>Group 3.1(0.79)</td>
<td>Group 3.1(0.79)</td>
<td>3.0(0.60)</td>
<td>F 0.46</td>
<td>0.74</td>
<td>9.58**</td>
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<td>Pity</td>
<td>Single 1.8(0.83)</td>
<td>Group 1.9(1.01)</td>
<td>Group 1.9(1.01)</td>
<td>2.3(1.16)</td>
<td>F 0.10</td>
<td>3.07*</td>
<td>1.5</td>
</tr>
<tr>
<td>Social</td>
<td>Single 2.4(0.68)</td>
<td>Group 2.1(0.74)</td>
<td>Group 2.1(0.74)</td>
<td>2.4(0.87)</td>
<td>F 0.01</td>
<td>0.10</td>
<td>4.56*</td>
</tr>
</tbody>
</table>

* signifies that p < .05, ** signifies that p < .01

Table 4. Stereotypes: Big Five, Godspeed, Ezer Analogies, Work Context, Situational Appraisals of Robots

<table>
<thead>
<tr>
<th>Stereotypes</th>
<th>NAO M(SD)</th>
<th>Pleo M(SD)</th>
<th>iCreate M(SD)</th>
<th>Num F(1,121)</th>
<th>Type F(2,121)</th>
<th>M(SD)</th>
<th>Type F(2,121)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Five</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Agreeable</td>
<td>Single -0.9(2.16)</td>
<td>Group -0.6(2.04)</td>
<td>Group -0.6(2.04)</td>
<td>0.9(2.42)</td>
<td>F 0.86</td>
<td>3.37*</td>
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<td>3.6(0.47)</td>
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<td>3.3(0.54)</td>
<td>F 4.38*</td>
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<td>Group 2.8(1.30)</td>
<td>Group 2.8(1.30)</td>
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<td>3.6(1.33)</td>
<td>2.1(0.76)</td>
<td>F 0.28</td>
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<td>Group 4.3(0.88)</td>
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<td>3.1(1.17)</td>
<td>3.6(1.19)</td>
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<td>Group 4.4(1.24)</td>
<td>Group 4.4(1.24)</td>
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<td>4.5(1.34)</td>
<td>4.9(0.31)</td>
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<td>Group 3.4(1.08)</td>
<td>Group 3.4(1.08)</td>
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<td>Group 1.6(0.93)</td>
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<td>3.2(1.26)</td>
<td>3.1(1.05)</td>
<td>F 0.43</td>
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* signifies that p < .05, ** signifies that p < .01
**Work contexts**: Participants rated “which contexts [you think] robots should work in” on a 1 (Not at all) to 5 (To a great extent) scale. No main effects were found, but several interaction effects were significant. In general, Group Pleos elicited significantly decreased ratings (i.e. ‘robots should not work in [context]’) compared to Single Pleos. Specifically, Group Pleos had lower scores than Single Pleos for numerous contexts, including resorts, offices, police stations, shopping areas, hospitals, and homes (all \(p < .05\)). In contrast, Group NAOs generally elicited nonsignificant increases in work context scores compared to Single NAOs, including one statistically significant increase for “working in factories” (\(p = .01\)). There was also a Number x Type interaction effect for ‘dangerous areas’ (\(p = .01\)), such that Group iCreatives elicited lower scores than Single iCreatives (\(p < .01\)), while Pleos and NAOs did not significantly change across Number.

**Situational Appraisals of Robots.** Participants rated a number of situational appraisals involving the trust of robots from 1 (Strongly disagree) to 5 (Strongly agree). Higher numbers indicated greater willingness to trust robots in these scenarios.

Higher ratings tended to be found for Group than Single NAOs and lower ratings for Group than Single iCreatives. Overall, there were few main effects (Number or Type), but a larger number of Number x Type interactions. Specific items with statistical significance are below, listed by type of result (i.e. main effect or interaction effect).

**Type**: Participants who viewed NAOs were more likely to trust robots to hold their personal possessions than Pleos and iCreatives (\(p < .05\)).

**Interaction effects**: Participants showed more trust for Group than Single NAOs for robots teaching children, being in their own homes, holding their personal possessions, and telling robots about personal secrets (\(p < .05\)). Conversely, less trust was shown for Group than Single iCreatives for having a robot invest their money in the stock market (\(p < .05\)). No significant effects were seen for: robots cooking food, helping you walk, tutoring, reminding you about medicine, helping with an injury, talking about something personal, or talking about a friend.

5. **Discussion**

Our primary interest was in examining the influence of robot number and type on a variety of variables, such as attitudes, emotions, and stereotypes. In this study, participants (between-subjects) were shown a video of robots differing in Number (Single, Group) and Type (NAO, Pleo, iCreate), and then they completed questionnaires that measure social responses.

Interestingly, we found strong evidence that instead of number or type of the robot videos influencing these social variables, it was generally the interaction between these two factors that best accounted for the observed results. This pattern was consistent across the measures for attitudes, emotions, and stereotypes toward robots. Below, we discuss the main findings.

First, introducing groups of iCreatives increased negative responses, such as self-reported threat, anxiety, fear, and lack of trust, compared to single iCreatives. We found this across several item scales (see Tables 2-4). The increase in negative emotions (e.g., threat, fear, disliking) may have influenced diverse aspects of social perception, such as situational appraisals (e.g., trusting robots in different scenarios) and work contexts. For instance, viewing a group of iCreatives led to participants being less likely to want robots to teach children, have a presence in their home, and invest in the stock market for them.

Second, viewing groups of NAOs tended to elicit more positive responses than viewing a single NAO. This was apparent in a wide variety of scales that measured general affect (e.g., liking, disliking, feeling positive), emotions (e.g., anxiety, fear, gratefulness), perceived threat, and trust.

Third, viewing groups of Pleos led to other, unique effects. Unlike with NAOs and iCreatives, Group Pleos seldom elicited more positive or negative responses than Single Pleos. Instead, viewing Group Pleos elicited changes in more descriptive characteristics of robots (i.e. stereotypes), including analogies and future work contexts. For example, participants exposed to Group Pleo videos rated robots in general as less like servants or friends, and less likely to be part of the future workplace (overall), compared to participants who viewed Single Pleos. These types of changes were observed less frequently in NAOs and iCreatives.

5.1 **Proposed Explanations**

To account for the findings of this exploratory study, we offer three explanations, which are based on the notions that (1) Observing groups of robots reveals novel types of information about the robots that cannot be observed from single robots and (2) Observing many instead of just one robot increases the salience of the distinction between humans and robots, causing the human observer to categorize him or herself as human [18].

Our first potential explanation involving the above notions is that a robot’s degree of perceived sociality may influence social psychological variables that are (directly or indirectly) relevant to social interactions. A group of robots can display a variety of social behaviors that are impossible to convey in isolation, such as social intelligence, behavior coordination among individuals, and shared goal pursuit. These features may all affect observers’ own social perceptions of the robots—for instance, causing them to like robots more (e.g., if they appear socially competent) [7, 8].

Second, intergroup dynamics may influence responses to robots, by changing perceived intergroup competition and perceived threat. As previously noted, observing multiple robots may cause observers to self-categorize as humans, which in turn will focus attention on differences between humans and robots [18]. Thus, the robots most dissimilar to humans (mechanomorphic) may seem even less human-like in groups, reducing liking for them. In contrast, a group of anthropomorphic robots may be more likely to be classified as “like me” or “human” when there are many of them, as opposed to one. Not only the robots’ form, but their display of social behaviors that either are human-like or not may be especially strong contributors to social categorization and the resulting processes. Beyond our specific study, numerous social behaviors, including emotional contagion, within-group competition, and swarm behavior may be observable with groups of robots. Each of these behaviors may have important consequences for future social interactions with the robots. For example, an individual who infers that a group of robots are likely to stick together (e.g., based on their highly coordinated behavior) may perceive higher intergroup competition, possibly resulting in more negative attitudes and emotions towards those robots [24].

Third, level of anthropomorphism may affect a wide variety of social and non-social variables. Observing robots interact with each other can provide information about whether robots are “human-like” or not [13]. Previous research suggests that relational actions, rather than simply object form, can lead people to apply anthropomorphic interaction schemas to inanimate objects (e.g., geometric shapes), including emotions such as anger and fear [36]. People may also bring other types of non-
anthropomorphic interpretations to different relational actions depending on the interaction schema triggered by the robots’ relational behaviors toward each other. Robot groups that are not seen as displaying human-like social behaviors may be perceived as less human-like, which can impact social perception in many ways. This study provides preliminary evidence that information given by group behavior, is sometimes more potent or informative than information given by robot type alone in determining social responses to robots. In the study, this was evidenced by the relative lack of main effects of Type on social responses, compared to the large amount of Number x Type interaction effects (i.e. more positive or more negative depending on Number and Type), which showed robots interacting relationally.

Social behaviors may be perceived along other spectrums, such as zoomorphism (i.e., similarity to animals). In the case of Group Pleos, we suggest that their group social behaviors (e.g., grazing) may have prompted participants to see them as more animal-like, consequentially leading to decreases in certain social perceptions (such as Group Pleos being less “like friends”, less “like servants”, and less likely to be seen in future work contexts, as would be expected for zoomorphic entities).

These three explanations are highly complementary with each other. For a specific example, degree of sociality and intergroup dynamics may exert a bidirectional influence on each other, such that observing a highly agreeable and sociable robot may decrease perceived threat, and vice versa. Further, an observed behavior may impact two or more of these features simultaneously. For example, swarm behavior (e.g., intelligent behavior arising from the group, rather than from individuals) may make observers judge robots as more threatening and less anthropomorphic. The intent of separating these three features is not to suggest that they are fully disassociated, but rather to emphasize that they may each exert some unique effects on social perception (in addition to their shared influence).

5.2 Limitations and Future Work

The social psychological literature presented earlier shows a strong emphasis on the generally negative consequences of perceiving groups of people versus individuals, although the effects can be positive under specific circumstances. Viewing others in a group context often increases anxiety, anger, intergroup competition, and other undesirable social consequences. We found large variation in whether introducing a group context improved or damaged social perception towards different types of robots.

One potential explanation of these observed differences is that they were mediated by the valence of the robot videos. It is possible, for instance, that certain robot videos (e.g., NAOs) may have induced positive emotions while others (e.g., iCreate) did not. Positively valenced videos may have caused more positive social responses toward robots, while negatively valenced videos made responses more negative. While this hypothesis is currently not possible to reject, videos were created using only behaviors that the robots could perform, and thus, the valence of each video rested in the perceived valence of robot types, behaviors, and interactions. Further, the valence alone does not account for the highly specific effects of the videos on social variables, such as changes in expected work contexts for group Pleos.

A limitation of this paper is that in some Group conditions we used two robots (NAO), and in some we used three (Pleo, iCreate). Although this was less than ideal, evidence on the discontinuity effect [26] suggests that it would not have a great influence on responses to robots. Further, our results do not suggest that the pattern of responses to groups of robots is directly affected by the number (two or three) of robots. For example, we did not find that people respond negatively to two robots, and even more negatively to three. Thus, we find it unlikely that the differing numbers affected the results – though it is a constraint of our study occasioned by our lack of access to three NAOs.

Because participants in this study answered questions about their attitudes, emotions, and stereotypes toward robots in general, we cannot conclude what participants thought of the specific robots they watched in the videos and what types of robots they were thinking of during the study. We propose that it is likely that participants’ emotions, attitudes, and stereotypes towards robots were assimilated toward their responses for the specific, observed robots (i.e., what they thought of the robots in the video, they projected to robots in general). We believe this is likely because non-extreme primes (i.e. video featuring robots that are not significantly different than other robots, in general) generally produce assimilation effects [37]. However, further research should be done to confirm this hypothesis.

This study suggests that robot-robot interaction influences human perceptions of robots. In a world in which robots are becoming increasingly prevalent, understanding these effects will be critical for designing appropriate environments for humans and robots. This was an exploratory study, and we suggest further research to examine the details of the effects of robot-robot interaction. We are beginning further research to test if these findings of responses to videos of robots in this study can generalize to interaction with physically present robots (single or group). We are also investigating specifically what social behaviors and qualities people interpret in the videos of multiple robots we showed.

In this study, we found that people generally respond more positively to anthropomorphic robots in groups than singly, whereas mechanomorphic robots in groups increase negative responses. This research is relevant to places such as the Robot House in Hertfordshire that keep only one robot operational at a time in an attempt to reduce human anxiety [38]. This study suggests that multiple robots could operate at once without increasing anxiety if the robots are anthropomorphic. Because anthropomorphic robots, such as NAOs, are viewed more positively in groups than singly, they may be more marketable in groups. Future research might also benefit from examining mixed robot groups (akin to the fictional duo of humanoid C3PO and mechanomorphic R2D2) in order to understand how people might respond to groups involving several different types of robots.

6. ACKNOWLEDGMENTS

Our thanks to the Social Science Research Center (SSRC) at Indiana University for funding this project. Thank you to Cindy Bethel, Stephanie Wuisan, and Dexter Duckworth for recording the group-NAO video, to Chen Yu and Linguer Xu for assistance with the single-NAO video, to IU’s Cognitive Science Program for their loan of three Pleos, and to Matthew Francisco and Kartik Adur for building the iCreate for the videos. Thank you also to Kate Shaw, Christina Wehrmann, Tasha Smith, Jingsha Liu, and Catherine Sembroski for running participants.

7. REFERENCES


