Robot Social Presence and Gender: Do Females View Robots Differently than Males?

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ABSTRACT

Social-psychological processes in humans will play an important role in long-term human-robot interactions. This study investigates people's perceptions of social presence in robots during (relatively) short interactions. Findings indicate that males tend to think of the robot as more human-like and accordingly show some evidence of "social facilitation" on an arithmetic task as well as more socially desirable responding on a survey administered by a robot. In contrast, females saw the robot as more machine-like, exhibited less socially desirable responding to the robot's survey, and were not socially facilitated by the robot while engaged in the arithmetic tasks. Various alternative accounts of these findings are explored and the implications of these results for future work are discussed.

Categories and Subject Descriptors

I.2 [**Computing Methodologies**]: Artificial Intelligence—*Robotics*

General Terms

Experimentation, Human Factors

Keywords

human-robot interaction, robot social presence

1. INTRODUCTION

Today, many researchers as well as several government officials envision robots to become part of people's households in the future, as robotic assistants, personal robots, or robot companions. The resultant interactions between humans and robots, however, require a high level of sensitivity on the part of robot designers to the nature of human social interactions and human social expectations, much more so than in current short-term HRI scenarios. While many important questions about the social influences of robots that are collocated (i.e., in the same space) with humans are currently open, it seems clear that an answer will depend, at least in part, on how humans perceive and think about their robotic companions, critically involving characteristics related to the robot itself [10]. For example, when an autonomous mobile robot, about the size of a human, is capable of natural language interactions, and can seemingly demonstrate self-directed behavior, human observers have a strong tendency to attribute human-like qualities to it [5]. Under these circumstances, it might well be expected that a robot will invoke in a proximal human companion certain social-psychological processes that could affect the human's behavior in ways similar to how that companion would be affected by the presence of another human [11].

The overall aim of this paper is to contribute to a better understanding of how humans perceive robots, since those perceptions will influence their expectations with regard to robots. The more closely robot behaviors match expectations, the more comfortable and effective humans will be interacting with them. Although it may seem natural to assume that robots are viewed as "human-like" by human peers, it is important to verify that assumption before constructing robot architectures based on it. People may view robots completely differently than expected, and it is unlikely that there is a single, homogeneous perspective. For example, there is some evidence that factors such as gender may affect subjects' attitudes toward robots [2, 9].

Our approach is to gauge robot social presence (i.e., the degree to which people perceive human-like characteristics in the robot peer [17]) by comparing subjects' behaviors during interactions with a robot to reactions predicted by two well-established social-psychological effects of human collocation. The first is based on disclosure results from earlier work in human-computer interaction demonstrating that people are more truthful when interacting with computers [13, 12]. If people view robots more like humans than like computers one would expect them to be less truthful when answering questions asked by a robot than when answering questions by themselves on a paper-and-pencil survey. We will test this hypothesis by having a robot administer a survey to a human.

The second method is based on *social facilitation* [20], an interesting effect that humans exhibit in the presence of other humans: performance on well-rehearsed easy tasks is typically higher when other humans are collocated as compared to when the task is performed alone, while performance on less well-rehearsed tasks is typically lower when other humans are collocated than when performed alone.

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To the extent that people view robots as human-like, they should exhibit a social facilitation effect on well-rehearsed easy and hard tasks in the presence of a robot as compared to performing those tasks alone. Hence, we will have subjects perform two simple arithmetic tasks (one easy, one hard) to determine the extent to which the presence of a robot during task performance influences the outcome of those tasks.

2. BACKGROUND

The two social-psychological phenomena we take as evidence for human perception of robot social presence (i.e., disclosure and social facilitation) have been the subjects of many studies. Disclosure was investigated in the context of human-computer interaction by [13] and [12]. These investigators wondered if humans would respond to computers differently if their display characteristics were more human-like than machine-like and discovered that by making a computer's style of interaction with the user more conversational, affect-laden, and humorous, it was perceived as being more human-like and was reacted to in social-psychological ways that were more distinctly characteristic of interactions among humans. For example, [13] discovered that when the human-like computer interface was used to deliver computerized testing, quiz performance was better and students spent more time thinking about test items than when a more machine-like interface was employed. In a follow-up study, [12] replicated this finding with human-like and machine-like interfaces during computerized testing, and also noted that improved performance was limited to less difficult, rather than more difficult test items.

These findings were reminiscent of the above-mentioned *social facilitation* and in the context of human-computer interaction research reinforced the emerging view at that time that social-psychological perspectives were important in understanding how humans and computers could work together more effectively [6].

Along with the possibility that a human-like computer could engender something similar to social facilitation in users, an early report by [19] further suggested that people might be more willing to disclose intimate information to an interactive computer than they would be to another human. This suggestion was based on anecdotal observations of how people interacted with ELIZA, a program emulating a Rogerian psychotherapist. Not only did people ascribe human-like qualities to ELIZA, but they also appeared to be very open and honest with the machine, quite possibly more so than with a human psychotherapist (see [19]).

Considerable subsequent work has examined the comparability of human responses gathered under various modes of collection including interviews, paper and pencil surveys, and computerized interviews or surveys. One early study ([7]) revealed that subjects answered close-ended questions on a traditional paper and pencil survey in ways that were more socially desirable and less extreme than they did in responding to the same questions on an electronic survey. An extensive review and meta-analysis has confirmed computer-based surveys are less prone to distortion from response bias or social desirability effects than other more traditional forms of data gathering including face-to-face interviews and paper and pencil surveys [14].

One common interpretation of the finding that people may be more open and less biased when responding to a computer than a person (or a paper survey that will be given to a person for scoring) is that the real or implied presence of a human who is closely linked to the survey can produce a kind of anxiety in the respondent about the possibility of being evaluated or judged by that human [18]. Given such a concern, survey respondents may intentionally or unintentionally respond in ways that "save face" or mitigate the possibility that they may look bad in the eyes of others. That this anxiety is more likely to occur in respondents with face-to-face interviews or even with paper surveys than with computerized instruments is believed to reflect a more direct link between a real or implied human in the former cases than in the latter. As [18] suggest, right or wrong, there may be a common tendency to regard computer-mediated responding as being a more private and anonymous form of communication, one less directly tied to a human presence.

Interestingly, this notion of evaluation anxiety is also linked to the phenomenon of social facilitation [3, 4]. The idea here is that the presence of a collocated human observer can create evaluation anxiety in someone who is performing a task in the presence of the observer. Such anxiety is believed to exacerbate general drive levels thereby potentially enhancing performance on easy tasks, but possibly competing with performance on more difficult tasks.

The overall purpose of the present study was to explore social presence in human-robot interaction: how human-like are robots perceived to be? In pursuit of this question, this study involved three specific goals. One was to compare how subjects responded to a survey administered vocally by the robot with their responses to the same survey on paper completed when they were alone. Our hypothesis here was that there should be a direct relationship between the extent to which the robot was viewed as human-like and the amount of response bias. Based on the suggestions noted above that response bias is related to the real or implied presence of a human clearly linked to the survey, a robot viewed as human-like might engender more rather than less response bias. In contrast, if the robot were viewed as more computer-like (i.e., machine-like), then response bias could decrease in the presence of the robot, relative to a paper survey.

A second goal of this study was to see if an autonomous robot would engender social facilitation in people performing both easy and more difficult tasks in the robot's presence. Our hypothesis was that if subjects did in fact ascribe human-like qualities to an autonomous robot, then task performance might well be affected in ways consistent with social facilitation when subjects worked in the presence of the robot, compared to when they worked alone.

A third goal was to assess the comparability of findings for males and females in our study. While no specific hypothesis was advanced in connection with this goal, gender effects have been observed in other technology-related areas like computer-mediated communication (cf. [18]).

3. METHODS

The experiment consisted of three phases: a survey, two simple arithmetic tasks, and another survey. We employed a within-subjects design with one robot condition (*robot-first* vs *robot-second*), one gender condition (*male* vs *female*), and an order condition for the arithmetic tasks (*easy-hard* vs *hard-easy*).

Participants: 47 subjects, 24 males and 23 females, were recruited from a pool of undergraduates including engineering students and students in general education Psychology courses, ensuring a broad sampling of majors.

Experimental Setup: Subjects were seated at a desk in an enclosed room of approximately 5m x 6m. During the whole experiment no humans other than the subject were in the room. In the *robot-first* condition the robot was present during the survey and arithmetic tasks (after which it left the room), while in the *robot-second* condition the robot was visible only during the second survey (it was hidden behind a screen during the first survey and the arithmetic tasks so that subjects could not see it until it came out for the second survey). The robot was fully autonomous during the whole survey taking procedure.

Figure 1: The robot used in the experiment.

Materials: Surveys 1 and 2 consisted of the same set of 25 items developed specifically for this study. Two categories of items were used: *Robot Items* (e.g., "I don't think it is right to mistreat or abuse a robot."), *Personal Items* (e.g., "There are times when I have had too much to drink."). These items are listed in Table 1. In addition, the last five items shown in Table 1 were taken from the *Marlowe-Crowne Social Desirability Scale* and selected to maintain comparability with the same items reported by [7]. Finally, Survey 1 also had the remaining 28 *Marlowe-Crowne* items.

Procedure: Subjects were randomly assigned to one of the two robot conditions. Those in the *robot-first* condition were introduced to the robot at the start of the experiment. The experimenter directed the robot to move to the desk where the subject was seated, asked it to perform the survey, and left the room. Before presenting the first item, the robot verbally explained to the subjects the numeric code to be used for responses. The robot then presented all items on the first survey (the 30 items from Table 1 plus 28 additional items from the *Marlowe-Crowne Scale*). Survey items were presented verbally, and subjects responded verbally.

When the first survey was complete, the experimenter returned to the room and asked the subjects to perform two ("easy" and "hard") arithmetic tasks. The "easy" task consisted of multiplying a two-digit by a one-digit number, while the "hard" task consisted of multiplying a three-digit by a two-digit number. The order of the easy and hard arithmetic tasks were counterbalanced between subjects. Subjects began each arithmetic task after the experimenter left the room; the robot remained in the room near the desk throughout both tasks but did not interact with the subjects. The problems were given on paper and subjects used a pencil to solve them. Subjects were asked to complete as many problems as possible as accurately as possible within 5 minutes.

Upon completion of the arithmetic tasks, the experimenter removed the robot from the room and gave subjects the second survey, which they filled out alone using paper and pencil. After subjects were done with the second survey they left the experiment room and were debriefed.

The *robot-second* condition was conducted in an analogous manner, with the main difference being that the robot was hidden behind a screen (and thus not visible to subjects) until the second survey was conducted. At that point the robot emerged and conducted Survey 2 in the same way it conducted Survey 1 in the *robot-first* condition, except that the last 28 *Marlowe-Crowne Scale* items were omitted. The experiment lasted for about 45 minutes in either condition.

Equipment: We used an ActivMedia Peoplebot (P2DXE) with two Unibrain fire-wire cameras mounted on a Directed Perception pan-tilt unit, a Sick laser range finder, a Voice Tracker Array Microphone, and two speakers. The robot was controlled by two on-board laptops (with 1.3 GHz and 2.0 GHz Pentium M processors, respectively) running Linux 2.6.12 kernels. The laptops were connected via wired Ethernet and had wireless connections to the outside that were used exclusively for the purpose of starting and stopping robot operation. We employed our distributed integrated affect, reflection, cognition DIARC architecture used successfully in previous HRI experiments [16, 1, 15].

4. RESULTS AND ANALYSIS

We conducted several extensive analyses on the data. For purposes of clarity, we will separate the presentation of the results below, first according to the goal of examining the comparability of robot vs paper survey administration, and second according to the goal of examining possible social facilitation effects.

4.1 Robot vs paper survey administration

There are three parts to this analysis. First we examined responses to only the Survey 1 items. We begin with Survey 1 because there are *a priori* reasons for concern about possible contamination by carryover on Survey 2 that may obscure interesting effects in a broader analysis of both surveys. Moreover, as this is the first time the survey has been administered, we need to refine the scales for robot attitude and personal disclosure on the uncontaminated sample of Survey 1. For this purpose, we performed factor analysis on the survey responses and made a between-subjects comparison of the *alone* (i.e., *alone-first*) and *with-robot* (i.e., *alone-second*) conditions with respect to Survey 1. We then look at the same analyses for Survey 2 before finally using a within-subjects test to compare Survey 1 and Survey 2

Table 1: All items that occur both on Survey 1 and Survey 2. Items 1 through 25 were answered on a scale from 1 to 6 with "1 = strongly disagree," "2 = moderately disagree," "3 = slightly disagree," "4 = slightly agree," "5 = moderately agree," "6 = strongly agree," while items 26 through 30 were "true-false" items from the *Marlowe-Crowne Social Desirability Scale*. Robot-related items are in bold.

1. **Robots are autonomous, self-contained beings, unlike like puppets who need to have someone pulling their strings.**
2. There are times when I have done things of which I'm proud.
3. **Robots should be able to recognize human emotions.**
4. **I don't think it is right to mistreat or abuse a robot.**
5. There are times when I have gone out with friends.
6. There are times when I have watched TV.
7. There are times when I have made copies of software programs even though the copyright or license agreement didn't permit it.
8. **Robots should have rights just like pets or people.**
9. There are times when I have listened to music.
10. **I would have no problem taking orders from a capable robot who had been designated by my boss as my team leader.**
11. **Robots would make good companions to have around the house**.
12. **I would prefer to have a robot at home rather than a pet.**
13. **It is useful for robots to be capable of understanding what humans say.**
14. **Robots have their own personalities.**
15. **I would have no problem learning from a capable robot who was my instructor for a course or a task.**
16. There are times when I did not tell the truth.
17. **Robots can have feelings.**
18. There are times when I did not hand in my own work.
19. There are times when I have download or copied music even though the copyright or license agreement didn't permit it.
20. There are times when I have used the Internet to gamble or place bets.
21. **I would have no problem working with a capable robot as a member of my work team.**
22. There are times when I have had too much to drink.
23. **Robots should have emotions of their own.**
24. There are times when I have done things of which I'm ashamed.
25. There are times when I have eaten some ice cream.

26. I am always careful about my manner of dress.
27. I always try to practice what I preach.
28. When I don't know something I don't at all mind admitting it.
29. I would never think of letting someone else be punished for my wrongdoings.
30. I never resent being asked to return a favor.

responses for each condition to check for order effects. And finally, we examined the five items from the *Marlowe-Crowne Scale* at the bottom of Table 1 to assess possible response bias.

4.1.1 Survey 1

The primary interest here was to determine if the robot's presence would affect the way subjects respond to survey items. In addition, we were interested to determine if subjects' gender affected how they reacted to the robot and the survey. To test these hypotheses, we performed a preliminary factor analysis on subjects' responses to the survey items. Principal components analysis indicated two factors, which lined up closely with the robot-related questions and the remaining personal questions. Three items did not load on either factor (items 1, 7, and 20) and one loaded on both factors (item 13). These items were eliminated and the principal components analysis was repeated on the remaining 21 items. This yielded an explained variance of 5.24 (24.75% of the total) for the personal factor and 3.91 (18.65% of the total) for the robot factor. Based on this factor analysis, we analyzed the responses to the robot items and personal items separately, generating two factor scores (*RScore* and *PScore*) for each subject indicating his or her individual contribution to the corresponding factor. Higher values of *RScore* are taken to indicate more positive attitudes toward robots, whereas higher values of *PScore* are taken to indicate a greater level of disclosure (i.e., honesty) on the personal items, because higher responses on many of the personal items correspond to disclosure of negative actions or tendencies.

Looking first at the robot items, we performed a two-way 2x2 ANOVA on the dependent variable *RScore*[1] with independent variables *robot presence* and *gender*. No significant main effects were present, however, the interaction between *robot presence* and *gender* was significant ($F(1, 43) = 6.875, p = .012$, *female-alone* $M = -.579, SD = .79$, *female-robot* $M = .469, SD = 1.276$, *male-alone* $M = .275, SD = .784$, *male-robot* $M = -.126, SD = .882$). Figure 2 shows how female and male subjects respond differently to the robot's presence; female subjects who took the survey alone (i.e., using pencil and paper) tended to indicate a less positive attitude toward robots than female subjects who took the survey with the robot and less positive than male subjects who took the survey alone. Fisher's LSD test confirmed that these are significantly different, with $p = .011$ and $p = .032$, respectively.

A similar ANOVA performed for personal disclosure (*PScore*) indicated that *robot presence* was a significant main effect ($F(1, 43) = 4.166, p = .047$, *alone* $M = .288, SD =$

[1] An alternative to analyzing factor scores would be to analyze mean responses on each of the sub-scales and, in fact, we performed that analysis with similar results (i.e., no difference in significant effects or interactions found).

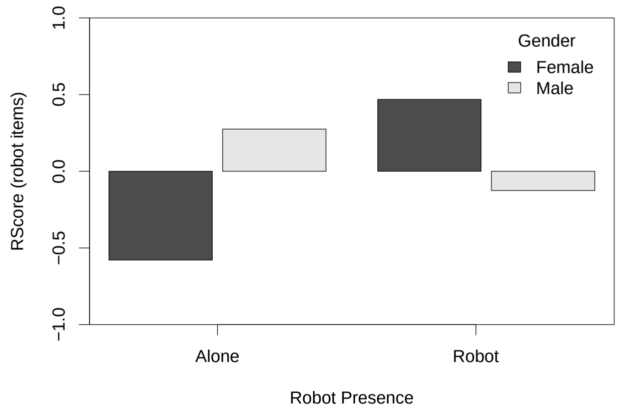

Figure 2: Average responses to robot items from Survey 1 broken down by *robot presence* and *gender*.

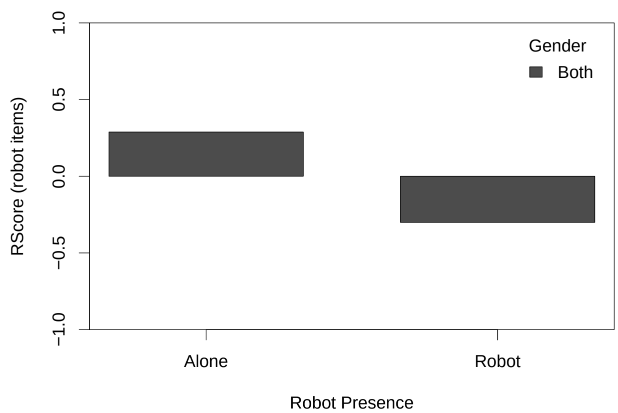

Figure 3: Average responses to personal items from Survey 1 broken down by *robot presence* and *gender*.

.303, *robot* $M = -.301, SD = 1.345$), but in this case there was no interaction with *gender*. Figure 3 shows the trend toward higher disclosure when alone than when with the robot. This result is congruent with subjects viewing the robot as more human-like than computer-like [13, 12].

4.1.2 Survey 2

For Survey 2, subjects changed conditions; those who completed the robot-administered survey first completed the paper-and-pencil survey and vice versa. We wanted to determine how subjects' reported views changed with the removal or introduction of the robot. The same 21 survey items as examined on Survey 1 were subjected to the principal components analysis, with the robot factor explaining 21.94% of the variance in responses (4.608) and the personal factor explaining 13.62% of the variance (2.86). Factor scores were again generated from this analysis for personal and robot factors and the results were subjected to separate 2x2 ANOVAS as for Survey 1. For the personal items, the

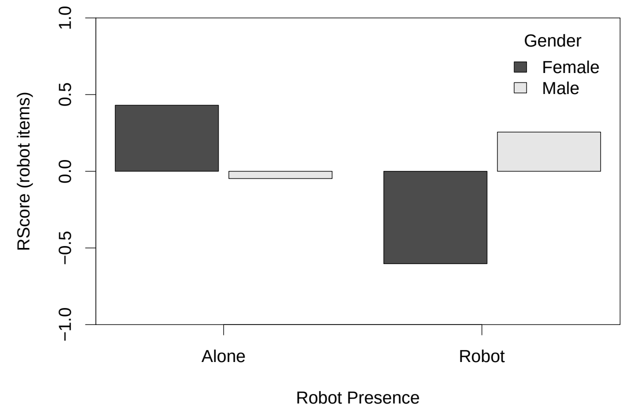

Figure 4: Average responses to robot items from Survey 2 broken down by *robot presence* and *gender*.

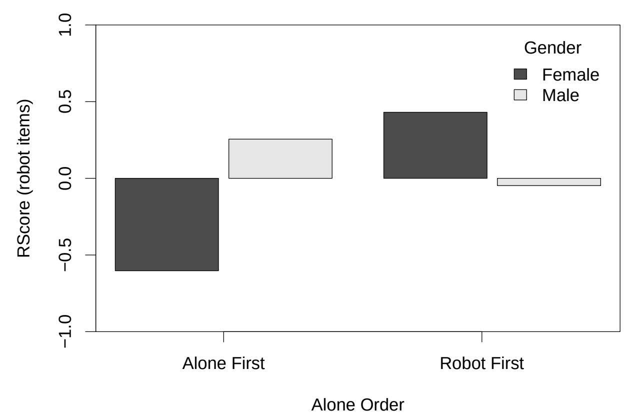

Figure 5: Average responses to robot items from Survey 2 broken down by *alone order* and *gender*.

ANOVA with *PScore* as the dependent variable and *robot presence* and *gender* as the independent variables found no significant main effects or interactions, different from the results of Survey 1 personal items. The presence of the robot had no effect on personal disclosure on Survey 2.

A similar analysis for the robot factor (with *RScore* as the dependent variable), however, indicated that the interaction between *robot presence* and *gender* was again significant $(F = (5.811), p = .02$, *female-alone* $M = .431, SD = .926$, *female-robot* $M = -.603, SD = .854$, *male-alone* $M = -.048, SD = 1.192$, *male-robot* $M = .256, SD = .771$). As with the comparable analysis for Survey 1, there were no significant main effects. Figure 4 depicts the interaction, and, surprisingly, the pattern is just the opposite of what was seen in Figure 2: on the second survey female subjects tended to view robots *less* positively when the robot was present. Fisher's LSD test confirmed that the *female-robot* value was significantly different from both the *female-alone* value ($p = .012$) and the *male-robot* value ($p = .032$). We

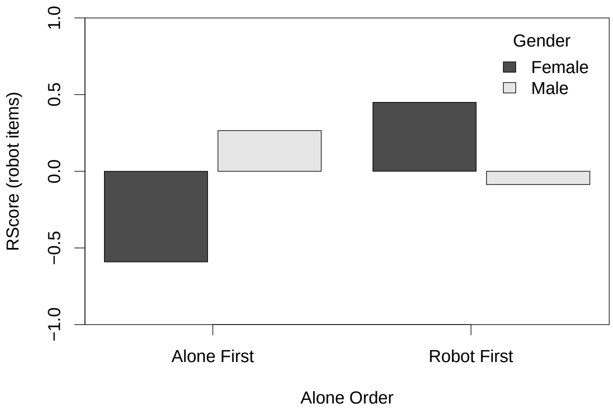

Figure 6: Average responses to robot items from both surveys broken down by *alone order* and *gender.*

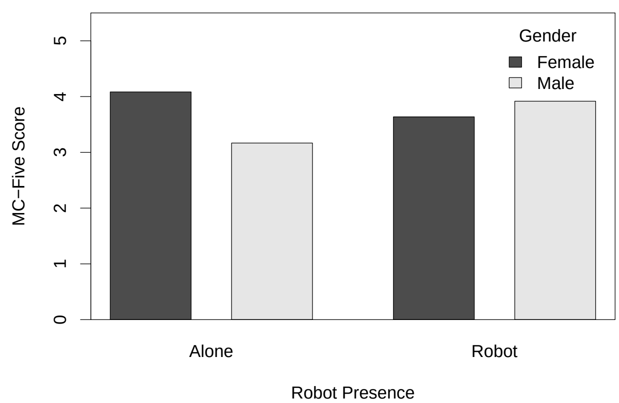

Figure 7: Marlowe-Crowne 5 scores for Survey 1 broken down by *robot presence* and *gender.*

think it likely that this reversal is due to a carry-over by subjects of the attitudes/responses given to Survey 1 to the new condition to which they were exposed for Survey 2. That is, for example, the females who were positively disposed to robots in the robot presence on Survey 1, were again positively disposed to the same questions in the alone condition of Survey 2. A similar carry-over seems to have occurred for the other groups as well (Figure 5). Of course, the possibility of such carry-over is a potential methodological disadvantage of administering the same survey to the same subjects twice with only a short intervening period.

4.1.3 Survey 1 vs Survey 2

Subsequent analysis confirmed the possible carry-over of attitudes/responses for the robot items. We conducted a three-way 2x2x2 mixed-model repeated measures ANOVA with *survey*, *alone order* (i.e., alone first then robot group vs. robot first then alone group), and *gender* as independent variables and *RScore* as the dependent variable. The only significant result was the *alone order* by *gender* interaction ($F(1, 43) = 6.97, p = .011$, *female-alone* $M = -.591, SD = .783$, *female-robot* $M = .45, SD = 1.081$, *male-alone* $M = .265, SD = .749$, *male-robot* $M = -.087, SD = .976$), depicted in Figure 6. Neither the survey effect nor any of its interactions was found to be significant. These results indicate that the responses of male and female subjects differed depending on whether they saw the robot first or second, a finding consistent with the possibility of carry-over.

4.1.4 Marlowe-Crowne Five Analysis

To assess the extent to which socially desirable responding was engendered under the paper vs robot administration procedures in effect for Survey 1, we analyzed the five items at the bottom of Table 1 taken from the Marlowe-Crowne Social Desirability Scale (i.e., MC-Five items). We selected these particular items because they had been shown in previous research to be sensitive to mode of survey administration (see [6]). According to the standard scoring procedures for these "true-false" scale items, subjects were assigned a 1 for "true" and a 0 for "false." A total score across these items was then computed for each subject, which had a maximum value of 5. Higher values of this score are thought to reflect a greater degree social desirability or response bias [6, 13].

We conducted a 2x2 between subjects ANOVA on the MC-Five total score for the independent variables Robot Presence and Gender (we limit the analysis to Survey 1 due to the previously-noted carry-over effects). Neither main effect emerged significant from this analysis, but a significant interaction effect was obtained ($F(1, 43) = 4.75, p < .04$, *female-alone* $M = 4.083, SD = .996$, *female-robot* $M = 3.636, SD = .674$, *male-alone* $M = 3.167, SD = .937$, *male-robot* $M = 3.916, SD = 1.084$). This analysis shows that the extent to which socially desirable responding was a joint function of both *robot presence* and *gender*. That is, males showed more response bias when alone than with the robot, whereas females showed the opposite trend. This is consistent with the survey findings above.

Table 2: Subjects' mean performance (in terms of "percent-correct") on the easy and hard arithmetic tasks grouped by gender and robot condition (standard deviations are given in parentheses). The only significant difference due to robot presence was among male subjects on the hard problems.

Problem-Robot Conditions	Male $M(SD)$	Female $M(SD)$
Easy with robot	95.91 (3.36)	97.00 (2.72)
Easy without robot	97.42 (3.18)	95.64 (3.82)
Hard with robot	63.18 (2.94)	67.27 (2.58)
Hard without robot	90.90 (1.10)	66.67 (2.87)

4.2 Social Facilitation Effects

We now turn to the analyses of the two arithmetic subtasks intended to measure potential social facilitation effects. We conducted a four-way 2x2x2x2 mixed ANOVA using a within-subject variable of *problem difficulty* (*easy* vs *hard*), and the independent between-subject variables of *problem order* (*easy-hard* vs *hard-easy*), *gender* (*male* vs *female*), and *robot* (*present* vs *absent*). The dependent variable for this analysis was *percent-correct* on each arithmetic task. We found a strongly significant main effect of difficulty ($F(1, 74) = 42.48, p < .001$) indicating that the categories "easy" and "hard" were justified for the two problem sets, and a marginally significant main effect of *robot* ($F(1, 74) = 3.16, p = .079$) indicating that the robot's presence did have an effect on the subjects' performance on the arithmetic problems. There was no main effect for *problem order* ($F(1, 74) = .67, p = .42$), which was expected. There was no main effect for *gender* either ($F(1, 74) = 2.51, p = .118$), indicating that males and females did not differ overall in their performance, although the relatively low p-value suggests some difference between males and females lurking behind the scenes. This difference was confirmed by a significant two-way interaction between *gender* and *robot* ($F(1, 74) = 3.99, p = .049$), a marginally significant two-way interaction between *robot* and *difficulty* ($F(1, 74) = 3.02, p = .086$), and a marginally significant three-way interaction of *gender*, *robot*, and *difficulty* ($F(1, 74) = 2.78, p < .1$), suggesting that the robot's presence had a different effect on males and females depending on the difficulty of the arithmetic problem.

In fact, as can be seen from the means in Table 2, the male subjects show much poorer performance in terms of percentage correct on the hard problems when the robot was present than when they were alone (from over 90% correct without the robot, to less than 67% correct with the robot, $t(12.757) = 2.7, p = .012$); none of the other three pairs showed any statistically significant difference between robot present and robot absent results. The lowered performance for males on difficult problems when the robot was present is consistent with what would be expected if the robot were viewed by them as human-like thereby producing social facilitation. In contrast, performance of the females was unaffected by the robot's presence in both difficulty conditions.

5. DISCUSSION

The most striking results of our investigation are the persistent differences between males and females, with respect to their ratings of the robot items, their socially desirable responding, and their performance on the hard arithmetic subtask with and without the robot. In trying to understand the reasons for these differences, one place to look might be the possible effects of the robot's voice, which in this case was distinctively male. A potential explanation based on the robot's male voice could be derived from the possibility that females might have reacted differently to the robot because it was perceived as being of the opposite sex, thus prompting more of a collaborative rather than competitive approach for this gender. In contrast, it could be argued that male subjects perceived the robot as masculine and thus adopted more of a competitive attitude towards it. The main problem with this type of explanation is that it does not seem to be supported by the Survey 1 data. If the male-female difference depended entirely on the robot's voice and no other factors, then we should have observed no difference in survey responses of males and female in the *alone* conditions. That is, males and females, without yet having interacted with the robot, should have had the same "baseline" views about it since they had not yet encountered its voice. However, the highly significant differences in male vs female ratings on Survey 1 strongly suggests that there might have been pre-existing differences along gender-based lines in viewpoints about robots.

Table 3: Subjects' mean ratings on the four post-experimental survey questions (standard deviations are given in parentheses).

Item	Male $M(SD)$	Female $M(SD)$
P1	3.43 (1.40)	4.11 (1.17)
P2	4.23 (.98)	5.22 (.83)
P3	4.14 (.90)	4.67 (1.00)
P4	3.88 (1.73)	3.88 (1.27)

Another (related) possible explanation is that it is the voice *per se*, rather than the gender of the voice, that accounts for the effects reported here. Previous studies have shown that even a disembodied voice can evoke social presence effects in subjects (e.g., see [8]). Hence, it is possible that the robot is only partially responsible for the results. However, there does appear to be at least *some* influence on the part of the robot, as evidenced by the fact that subjects' responses to the robot items remained unchanged between Survey 1 and Survey 2, whereas the robot's presence does not seem to have any effect on the Survey 2 personal item responses, even though it did have an impact on Survey 1. The voice effect should be present on both surveys, hence, if voice alone accounts for the differences, we should expect response patterns to be similar across both surveys on both personal and robot items, but that is not the case.

Further evidence in support of the possibility that females and males had different preconceived views of robots (both in general, and about the robot we employed in particular) comes from a post-experimental survey we conducted with the last 15 subjects (9 females and 7 males; the first 32 subjects were no longer available). The post-survey consisted of four questions where subjects had to rate their perception of the robot as (P1) "like a person=1" vs "like a surveillance camera=6", (P2) "like a person=1" vs "like a computer=6", (P3) "like a person=1" vs "like a remote-controlled vehicle", and (P4) "autonomous=1" vs "remotely controlled=6".

A 2x2 ANOVA with *gender* (*male* vs. *female*) and *item* ((P1) through (P4)) as between-subject factors, and item *ratings* as dependent variable showed significant main effects of *question* ($F(3, 56) = 6.159, p = .007$) and of *gender* ($F(1, 56) = 8.136, p = .019$), indicating that subjects gave different ratings and, more importantly, that female and male ratings differed significantly in their overall ratings (see Table 3). The lack of an interaction showed that the difference did not depend on the specific questions but was due to a general difference in how males and females view robots, with males indicating that robots were more like persons with autonomy. This apparent tendency for males to anthropomorphize the robot is consistent with the social facilitation effect we found for males with the difficult task inasmuch as we would have expected such facilitation only in those who attributed human-like qualities to the robot.[2]

[2]Note that the lack of any social facilitation effect on the easy problems, among either females or males, could be due to a several factors, including the short task duration (i.e., only 5 min.), or a ceiling effect due to the low difficulty level (i.e., it is difficult to improve over 95% correct).

However, it is doubtful that pre-existing differences in the views of female and male subjects toward robots can fully account for the present outcomes. Such differences do not easily explain the pattern of findings obtained throughout the study and in particular do not account for the "reversal" of male and female ratings discussed above in connection with Figure 4. More likely is yet a third possibility that subjects formed lasting opinions about robots based *both* on their pre-existing views *and* on the context (i.e., with and without the robot) in which they were first answering the survey items about the robot (including the particular attributes of the robot such as a male voice). If this "gender- and context-based priming" hypothesis is correct, then it may be important for the long-term acceptance of, and co-operation with, robots to design optimal gender-specific first encounters with robots taking into consideration of any pre-existing knowledge of or opinions about these artifacts.

6. CONCLUSION

The various behavioral and attitudinal differences in this study between females and males with regard to robots point to important possible distinctions in how males and females think about, react to, and possibly coexist with robotic entities. The challenge for future work is to isolate the effect of the robot from the effect of the voice *per se* and to further document and quantify the extent to which differences do exist along gender lines and the extent to which the robot's physical attributes play a role in these differences. Also important will be continuing efforts to understand how and why males and females may differ in their a priori views about robots. Finally, we are planning to do more detailed analyses of the individual survey items and their relationship to the independent variables using more advanced multi-variate techniques.

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