Effect of a Robot on User Perceptions

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Abstract— **Social robots, robots that help people as capable partners rather than as tools, are believed to be of greatest use for applications in entertainment, education, and healthcare because of their potential to be perceived as trusting, helpful, reliable, and engaging. This paper explores how the robot's physical presence influences a person's perception of these characteristics. The first study reported here demonstrates the differences between a robot and an animated character in terms a person's engagement and perceptions of the robot and character. The second study shows that this difference is a result of the physical presence of the robot and that a person's reactions would be similar even if the robot is not physically collocated. Implications to the design of socially communicative and interactive robots are discussed.**

Keywords- Human-robot interaction, robots, emotion and affective user interface, user studies

I. Introduction

Robots will some day be part of our everyday lives. Robotics research is advancing to the point where we can begin building robots to act as partners with us in domains such as education, healthcare, household work, entertainment, and scientific research.

What does it mean for a robot to act as a partner rather than as a tool? In general, we would expect the robot to act and react in many respects like a human does: to understand our directions to complete a task, to guide us in learning something new, and to assist us when we need a helping hand.

When building robots to interact with people in social ways, there are many important features of the robot that must be implemented well, such as having sufficient agility to complete their tasks, being robust enough for the environments they work in, and having an appearance acceptable to their desired audience. The aspects of social robots that we are concerned with here are mainly with regard to how people perceive them. When a robot is designed to be depended on by a person for completing a task, it must be seen as trustworthy. This is not a feature that we know how to turn off or on, so it likely has to do with how the robot interacts with a person. In interactions where a person is relying on a robot for information, they must believe that the information is credible. This is one feature of robots that we believe can be affected by causes such as the presence or proximity of the robot based on earlier research on interactions with on-screen agents [1, 2]. If information is being conveyed in a situation where a robot is teaching a person, then the robot must be capable of engaging the person in an interaction. As with other aspects of social robots, there are many issues that affect engagement, as a number of studies have shown [1-4].

Any type of robot that is used on a regular basis must be dependable. Being dependable will encourage people to build up trust in the robot, to believe that it will be consistent in its operations, and trust that it will be available when needed. What a person thinks about the robot's motives is important as well. In many types of interactions, a robot that is perceived to have the person's best interests in mind is desirable. An altruistic robot will often be viewed as beneficial to someone interacting with it.

We know that having a person (or even a computer) near to us, rather than further away, is more likely to influence our decisions [5-8]. Therefore it is likely that we want a robot to seem immediate and not remote when we are interacting with us. In tasks where the robot is conveying information to a person (such as giving directions, teaching a new skill, or collaborating towards a particular goal), it must be persuasive and believable. Computers have been shown to be more persuasive than humans in several studies [1, 9, 10], so this may not be difficult to accomplish.

When we begin to use robots in interactive situations where they must be cooperative, persuasive, and helpful, we must understand how to convey these qualities to the people with whom the robot will interact. We designed the following experiments to better understand people's reactions to social robots and how to build robots that fit these characteristics of interaction. We report our findings on people's engagement with and perceptions of robots when interacting with them.

II. First Experiment

Our first study was designed to investigate the differences in a person's response to a robotic character, an animated character, and a human to see how they compare along several measures. We report our findings on two questions: Is there is a difference in perceptions of the three characters? Do participants' levels of engagement differ between interactions with the three characters?

A. Theory and Hypotheses

The terms social presence, telepresence, and simply presence have all been used for the idea of how closely a mediated experience is to an actual, "live" experience. Lombard and Ditton describe the range of

Figure 1. Three characters used in first experiment

characteristics that these terms encompass in their recent work on measuring social presence [11]. Although we do not know of anyone using this type of measure to gauge the performance of a robot, we believe that this is a valid measure when comparing the performance of a robot and animated character. This is because the subscales of presence defined in Lombard and Ditton's work are the factors that are important in an interaction between a human and a robot.

We hypothesize that people will react differently to a person, a robot, and animated character on scales of credibility, enjoyableness of the interaction, fairness, reliability, and informativeness. Based on previous work, we anticipate that the human will be rated most highly, followed by the robot, and the animated character will be rated lowest.

B. Method

The design of this study was a within-subjects, repeated measures experiment. There were three characters that each participant interacted with: a human, a robot, and an animated character (see Figure 1). The order of presentation was varied across all six orderings.

1) Participants

Thirty-two participants ranged in age from 18 to 47 years of age (X = 27, SD = 9). Half the participants were male. Eighty-one percent of the participants were white, 9 percent were Asian, and 3 percent were each of African American, Hispanic, and other. Participants were students and professionals from the local community. None of the participants had seen the robot or animated character before.

2) Setup

The participant was seated across a table from three characters, a robot, an animated version of the robot, and a confederate. The participant was separated from each of the characters by a screen with a rectangular cutout approximately 3 inches by 7 inches. The participant could only see the eyes of each character, minimizing effects that might be caused by other differences across characters. Thus the support structure and motors of the robot were hidden, the rest of the flat-screen monitor was concealed, and the participant could not see the remainder of the face of the confederate.

On the table between the participant and each character were placed a red, a green, and a blue wooden block, each approximately 2 inches square. The distance between the characters was roughly 18 inches, allowing the participant to move after each interaction so that they were seated directly across from the character with which they were interacting. The other characters were hidden from the participant during each interaction. The participant was asked to adjust the height of their chair so that they were at eye level with the character.

3) Task

The participant responded to spoken requests from the characters, which asked the participant to manipulate the colored wooden blocks. There were nine requests made by the character to the participant during each of the interactions. Requests were presented in a female voice and in a different order by each of the characters. All requests required the participant to pick up and move one of the blocks and then replace it to its original position. Once a request by a character has been made, there was a fixed amount of time before the follow-up appeal is made. The time between finishing one request and starting the next was not fixed and subsequent requests commenced as soon as the participant has replaced the block from the previous action.

An example interaction is as follows:

Character: "Move that block off the table." The character looks down at the red block on the table for approximately three seconds and then looks back up at the participant.

The *participant* reaches for the red block and puts it in their lap or holds it up in the air.

Character: "Thank you. You can put it back now." The character is looking at the participant while speaking.

The *participant* places the block back on the table in the colored square where it belongs.

After a brief pause, the character makes the next request to the participant.

4) Characters

The characters were designed so that each would appear as similar to the others as possible. The robotic eyes have two degrees of freedom each: left-right and up-down. This gives them a 360-degree range of motion. Each eye also has upper and lower lids that can open and close.

The animated character was based on the robotic character and was created to look as similar as possible. The colors are matched, the movement is controlled in the same way as the movement of the robotic eyes, and their manifestation on the screen is such that they appear to be the same size as those of the robotic eyes.

Both the animated robotic characters were controlled by the same computer program, allowing them to act similarly to one another. The human also appeared to look in the same directions with similar timing. The human character was acted by the experimenter. As in the case of the other two characters, only the eyes of the human were visible.

We chose to create a character based only on the eyes for several reasons. A simple character makes it easier to create the same character in different media. With only eyes, it is also more feasible to do a comparison with a human with the rest of the face and body of the human hidden. It also becomes easier to attribute the findings of the study to the variable that we were changing: the modality with which the character was presented. A simpler character reduces potential confounding effects

Variable	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10
1. Liking	4.39	0.06	1									
2. Responsiveness	2.56	0.06	0.32*	1								
3. Positivity	3.85	0.06	0.63*	0.28*	1							
4. Looking	5.85	0.06	0.35*	-0.01	0.31*	1						
5. Involvement	4.72	0.06	0.53*	0.44*	0.59*	0.23+	1					
6. Enjoyable	4.63	0.07	0.72*	0.22**	0.41*	0.60*	0.41*	1				
7. Credible	4.27	0.07	0.60*	0.29*	0.73*	0.29**	0.64*	0.39*	1			
8. Fair	4.28	0.07	0.64*	0.14	0.44*	0.30*	0.31*	0.57*	0.53*	1		
9. Informative	3.87	0.07	0.57*	0.34*	0.44*	0.27**	0.63*	0.57*	0.57*	0.59*	1	
10. Reliability	3.99	0.07	0.67*	0.1	0.45*	0.47*	0.47*	0.67*	0.58*	0.66*	0.65*	1

**p < .01, *p<.05, +p<.10

TABLE I. CORRELATIONS FOR EXPERIMENT I SCALES

from participants' perceptions of other visual qualities of the character.

The differences between the interaction with a human in this experiment and a normal, everyday interpersonal interaction are obvious. However, it is difficult to make experimental comparisons between a robot of deliberately limited interaction capabilities and a human. For the measures that we were interested in comparing in this experiment, we decided that this setup would be the most useful. While we do make comparisons between reactions to the robot and to the human, we believe that more work should be done before more definite conclusions can be drawn from this information.

5) Protocol

We took a Wizard of Oz approach [12] to the design of this experiment, allowing the experimenter to exert the necessary level of control over the order and timing of interactions during the experiment. Using a prerecorded voice and preset timings for each exchange insured that each participant would have the same experience.

When a participant entered the room, she was seated in front of the three characters. Participants were pre-assigned an order in which they interacted with the three characters. The participant was read a short introduction to the experiment. This introduction informed them that they would be interacting with the three characters and explained the task to them.

The two characters not in use were covered and the participant was seated in front of the character with which she was first interacting. The blocks were placed in their positions, which were denoted by a color-coded cutout in the tabletop in which the block fit.

The interaction then commenced. At the conclusion of the interaction with each character, that character was covered, the blocks were moved to the next character, the participant moved in front of that character, and the character was uncovered. The participant then completed the other interactions. At the conclusion of the three interactions, participants completed a questionnaire about their experiences with the three characters.

6) Measures

The questionnaire given to participants consisted of four parts. These parts were designed or adapted from previous questionnaires to measure the characteristics of the interactions in which we are interested. Questions in the first two sections were taken from an earlier questionnaire [11] designed to measure five of the six dimensions of social presence. These sections also measured the level of engagement of the participants. The third section was comprised of a set of adjectives that describe the characters and the interactions.

7) Results

We performed a within-subjects, repeated measures ANOVA to examine how participants perceived the three characters. This analysis showed that participants perceived the robot to be only marginally different from the person overall but significantly different from the animated character (condition $F[2,2304] = 25.7$, $p < 0.0001$; robot vs. person contrast $F = 2.7$, $p = 0.10$; robot vs. character contrast $F = 27.4$, $p < 0.0001$). There was also an interaction between the character and the scales (interaction $F[8,2304] = 14.2$, $p < 0.0001$; see Table I).

	Sum of Squares	df	F	Sig.
Condition	64.3	2	25.8	0.0001
Attributes	172.7	4	34.6	0.0001
Condition x Attributes	141.2	8	14.2	0.0001

TABLE II. ANOVA OF CHARACTER ATTRIBUTES WITH THE CHARACTERS

The participants' perceptions of the character were measured on five scales: how enjoyable the interaction was, how fair the character was, how reliable the character was, how informative the character was, and how credible the information from the character was. The fairness and reliability scales showed no significant differences. However, on the scales of how enjoyable the interaction was, how credible the information from the character was, and how informative the character was, the robot was rated higher than the screen. (enjoyable $F[1,2335] = 10.12$, $p < 0.01$; credible $F[1,2335] = 7.55$, $p < 0.01$; informative $F[1,2335] = 3.84$, $p < 0.05$; see Table II)

	Sum of Squares	df	F	Sig.
Condition	164.5	2	60.5	0.0001
Engagement	2636.6	4	485.1	0.0001
Condition x Engagement	169	8	15.6	0.0001

TABLE III. ANOVA OF ENGAGEMENT WITH THE CHARACTERS

Engagement of participants was measured on five scales: how much they looked at the character, how much they liked the character, how involved they were in the interaction, how positively they viewed the characters' reactions, and what they thought about the responsiveness of the character. Participants viewed the robot as similar to the human, but significantly more engaging than the animated character. (robot compared to animated character $F[4,32] = 485.1$, $p < 0.0001$; see Table III)

While the robot was not perceived to be significantly different than the human in these interactions in most measures, the robot was seen as different than the animated character: it was more engaging, more enjoyable to interact with, and more informative and credible.

III. SECOND EXPERIMENT

An important result from the first experiment was the difference in participants' reactions to the robotic and animated characters. However, there is more than one reason why this disparity may occur. One cause could be that people see the robot as a real entity because it is physically in front of them, while they perceive the animated character as something that is not real because it is shown only on the screen. Another possible cause is simply the physical presence of the character. In this case, the difference would be from the animated character being perceived as though it is real, simply not physically in front of the viewer.

In other words, are the animated characters seen as real, but not present, or are they viewed as not real and simply a fictional character portrayed on the screen? To address this question, we designed a followup study. In this experiment, we control for the presence variable by having half of the participants interact with a physically present robot while the other half interact with the same robot presented on a television screen.

A. *Theory and Hypotheses*

There are a number of factors that influence a person's experience when interacting with a robot. One of the important factors is the level of trust that the person has for the robot. In any situation where a person relies on a robot, the interaction will be better when the person can trust the robot to act as expected.

In interactions where the robot is a source of information for a person, the person's beliefs about the quality of that information is important. Particularly in educational applications, the learner must be believe that the information coming from the robot is reliable. Nass, Fogg, and Moon's study on affiliation effects between people and computers [13] shows that people's sense of identification with a computer can be affected by the computer's behavior, so we believe the same will hold true for interactions with robots.

Knowing how engaged a person is in their interaction with the robot is an important indicator of the success of the robot in drawing the person in. According to Lombard and Ditton [14], when a participant is more engaged the experience is "a direct and natural experience rather than just the processing of symbolic data and is therefore likely to be more compelling." We are interested in measuring the level of engagement across the various cases of this experiment, both for direct comparison to one another and for comparison to the levels measured in the first experiment.

For applications of robotics in which the robot is intended to convince or inform a person on some topic, the ability of the robot to persuade is important. We hypothesize that when the robot is physically present, it will be viewed as more persuasive than in the telepresent case. Based on previous research of our own and of others, we hypothesize that a physically present robot will not be perceived differently than a remote robot.

B. *Method*

1) *Participants*

Eighty-two participants ranged in age from 18 to 61 (X = 27.7, S.D. = 9.7). The participant makeup is similar to that of the first study. The robot used was built for this study, so no participants had seen it previously.

2) *Setup*

For this experiment, participants were seated at a table. Directly across the table was either the robot or a twenty-inch television turned on its side (See Figure 2 for a picture of the robot). The television was placed so that it was in the plane that the robot occupied when it was standing straight up. Thus for half of the participants, the robot could actually lean out across the table towards them, while for the other half it only appeared to do so. When the robot was not physically present, it was set up in an adjacent room with a video camera to display the robot to the participant.

3) *Procedure*

There were two different tasks completed by participants in this study; half of the participants did each task, with each participant only doing one task.[1] The two tasks were the desert survival task and a teaching task. The former was developed by Lafferty and Eady [15] and was used by Nass, Fogg, and Moon in a similar study to ours, looking at the affiliations between humans and computers [13].

The teaching task had little interaction between the robot and the participant. In this task, the participant was read a lesson by the robot. During this phase of the experiment, the participant passively listens to the robot.

[1] Two tasks were used so that we could also make comparison between tasks; results of this comparison are reported elsewhere.

Variable	Mean	Std. Dev.	1	2	3	4	5	6	7	8
1. Sincerity	4.75	1.15	1							
2. Informative	2.8	1.13	-0.23**	1						
3. Dominance	3.3	1.12	-0.11	0.08	1					
4. Likeable	2.5	0.9	-0.50*	0.33*	0.13	1				
5. Reliability	4.27	1.54	0.30*	-0.46*	-0.18^{+}	-0.32*	1			
6. Open	2.59	1.06	0.40*	-0.24**	0.01	-0.26*	0.18	1		
7. Trustworthy	2.87	1.4	-0.48*	0.30*	0.32*	0.52*	-0.44*	-0.17**	1	
8. Engagement	3.6	1.08	0.36*	-0.07	-0.08	-0.20**	0.07	0.31*	-0.15	1

**p < .01, *p<.05, $^{+}$p<.10

TABLE IV. CORRELATIONS FOR EXPERIMENT 2 SCALES

After the lesson was read, the participant was asked a set of questions by the robot and answered them out loud.

4) Robot

The robot in this experiment was an elaboration on the robot used in the first experiment (see Figure 2). In this experiment, we wanted to take advantage of the fact that a robot shares the same physical space with the participant in the interaction.

Five degrees of freedom were added to the robot: the ability to turn at the base, to move forward from the base, forward and backward movement in the middle of the upright section, forward and backward movement at the top, and turn left and right at the top. This allowed the robot to move toward the user and the screen while maintaining proper orientation of its head. A face was also placed on the robot, giving it a more anthropomorphic appearance.

5) Protocol

Participants entered the room and were seated across a table from the robot. They were given instructions as to how to complete the task and the experimenter left the room. Completing the task took approximately four to five minutes, at which time the experimenter entered the room. Participants were then taken to another room to complete a questionnaire about their interaction.

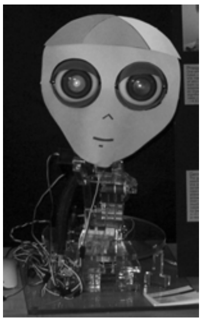

Figure 2. Robot used in second experiment

6) Measures

The questionnaire given to participants at the conclusion of the experiment contained scales for each of the measures described in the theory and hypotheses section: how trustworthy, altruistic, engaging, reliable, sincere, informative, enjoyable, frank, credible, and persuasive the robot was. During analysis, we reduced the number of measures because we are interested in whether participants' perceptions from the first experiment were still significant in the second experiment.

C. Results

We derived scales from the studies discussed in the theory section as well as our first experiment and confirmed them with factor analysis. This gave eight scales that accounted for 67.5% of the variance in participant responses (see Table 4). The scales are sincerity, informativeness, dominance, likeability, reliability, openness, trustworthiness, and participant engagement. The analysis showed that there was not a significant difference between the present and remote cases when participants were interacting with the robot.

IV. DISCUSSION

The first experiment looked at the effects of modality on a person's perception of the "other" with which they were interacting. We measured participants' level of engagement and their perceptions of the character in the interaction. We found that the robot was more engaging and rated more highly on the scales of perceptions than the animated character.

The results of this first experiment did not tell us what aspects of the robot make it different than the animated character. We had two hypotheses for an explanation. The first is that a robot is perceived differently than an animated character because of its physical presence or proximity to the person. If this hypothesis were true, the difference comes from the fact that the robot has a physical embodiment immediately in front of the person with whom it is interacting. The second hypothesis was that the robot is seen as a real entity, while the animated character is perceived as simply a fictional thing. If this were the case, it doesn't matter whether the robot is physically present; it's the fact that it physically exists somewhere that makes a difference to the person.

The second study examined the hypothesis that the difference results from the physical presence of the robot. In this case, half of our participants interacted with the robot while it was physically present, while the other half saw it on a television. In both cases, the robot responded in the same manner and with the same timings. What we found is that the presence of the robot does not make a significant difference in participants' responses. Therefore we are led to conclude that the second hypothesis is the one that explains the difference from the first study: it is not the presence of the robot that makes a difference, rather it is the fact that the robot is a real, physical thing, as opposed to the fictional animated character in the screen, that leads people to respond differently.

V. Conclusion

We began this paper by discussing some of the aspects of the way a robot is perceived that will affect its chances of success in interactions with people. These included the amount of impact a robot has in an interaction, the engagement of the person, and the effects of the task that the human and robot are engaged in. We were also interested in the difference between a robot and an on-screen character.

What we discovered is that a robot is an effective partner in an interaction because of its physical embodiment. Through our pair of experiments, we found that a robot is seen as more engaging than an animated character and is perceived as more credible and informative, as well as being more enjoyable to interact with. In previous work in sociable robotics, Breazeal [16] discusses creating robots in such a way as to take advantage of human social expectations. The idea behind this is a logical one that extends from research and observations of human interaction. It is still very difficult, if not impossible, to build a robot that can behave in a manner that is socially similar to an adult human. Breazeal's approach was to design a robot that was intended to be perceived as an infant, which directed people to interact with it in a particular way [17].

Overall, we see these studies as establishing some of the basic design parameters for robots that are intended to interact with humans in social situations. While there is more work to be done, the results presented here allow us to begin creating the kinds of interactions that will move human-robot interaction out of the lab in the near future.

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