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Socially Assistive Robotics for the Blind: Evaluation of a Small Humanoid Robot

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Abstract. *Engagement and motivation are important elements for successful educational processes. Researchers point out that humans tend to attribute life-like characteristics to robots and to socially engage with them, projecting intentions, goals, and emotions to them. In this study we have investigated, through a short-term experiment, blind persons perceptions of a physically collocated robot compared to a regular computer in regard to functional and social aspects. Results show that, in general, participants preferred to interact with the robot, demonstrating interest and being more engaged. In addition, our findings suggest that the physical embodiment evokes a positive attitude from the blind persons towards the robot propositions.*

1. Introduction

Human-Robot Interaction (HRI) is an area committed to understanding, designing, and evaluating robotic systems that work together with people. Socially Interactive Robots is a branch of HRI which focuses on robots to which human-robot social interaction is relevant [Fong et al. 2003]. The Socially Assistive Robotics (SAR) comprehends social robots that are also assistive, concentrating on helping human users through social instead of physical interaction.

SAR shares with assistive robotics the objectives to give assistance to humans, but presenting a whole new series of research challenges. Once it is understood how robots can interact with people, they can effectively and measurably help in the processes of training, and education. It may seem counterintuitive that physical robots can be used for social assistance, as software agents or other devices could be simpler options for that. However, research has shown that humans tend to attribute life-like characteristics to machines and to socially engage with them, especially robots, as they are embodied agents that have enough biological-like motion or appearance characteristics. People are used to engaging with physical machines, projecting intentions, goals, and emotions to them [Mataric et al. 2007].

Social behavior acts as a key role in assisting humans. Additionally, it seems even more important for people with special needs. The robot's physical embodiment, presence and appearance, and the robot's shared environment with the user are essential for creating a long-term engaging relationship. To establish a very complex and complete human-robot relationship, robots should exhibit human-oriented interaction skills and capacities, showing context awareness and social behavior that matches the needs of the user. In order to help the user achieve specific objectives, robots should focus attention and communications on the user [Matarić et al. 2007].

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Blind persons face many challenges in their daily activities, from finding their way to the right bus stop to identifying the actual bus they should take. While technology has been used to help people with disabilities in a variety of different and efficient ways, blind people still have many needs to be addressed [Brady et al. 2013].

As the interaction between humans and robots typically starts with the human seeing the robot, the appearance (e.g., size and posture) of a robot significantly impacts first initial impressions of sighted individuals and the consequent interaction [Min et al. 2015]. Therefore, blind persons perception of the robot might be different from that of a sighted individual.

One could argue that a physical embodiment is not important to a blind individual as that seems to be something only a sighted person would enjoy and perceive. Philosophers, however, have discussed how blind people actually ”see” with their hands since the 18th century [Paterson 2006]. These discussions try to understand the link between the senses and cognition. In our case, even though blind people perception might be different from that of a sighted person, they could still sense the embodiment of the robot.

The goal of this paper is to explore the attitudes of blind people towards a small socially assistive humanoid robot, focusing on which aspects of the robot's design can contribute to their engagement in the interaction, paying special attention to the robot's anthropomorphism. Using a short experiment, we tested whether the participants will prefer to interact with a robot, as it is anthropomorphically embodied, or with a laptop, which is only functionally embodied.

The following sections of this paper are organized as follows. In the next section, we present related work in the area of socially assistive robotics for blind persons. Section 3 describes main assumptions, hypotheses and research method that we have employed in the experiment. In Section 4, we discuss preliminary results and evaluate the perceptions of blind persons about the distinct interactions. We conclude the paper with a summary of the key research contributions of this work.

2. Background and Related Work

Assistive robotics is an area dedicated to aid or support human users in a variety of different situations, usually involving physical interaction, whereas socially interactive robots are those that focus on social human–robot interaction. SAR is defined as the intersection of assistive robotics and socially interactive robotics, specifying that robots should assist human users by means of social interaction rather than by physical contact [Fasola and Mataric 2012]. Thus, SAR is characterized as a way to help human users with special needs in their daily activities, having the possibility to enhance the quality of life of many individuals with different needs. Such users include individuals with cognitive disabilities or those going through physical rehabilitation as well as the elderly.

One of the main focus of SAR has been autistic children therapy. Robots have been used to capture and maintain attention, to stimulate joint attention and imitation, and to mediate turn-taking [Scassellati et al. 2012]. In addition, robots have been observed being used as mediators for the children's interactions with their teachers [Robins et al. 2005], allowing the children to share their experience with the researcher and with their caregiver.

A common design issue discussed in most SAR studies is the robot's embodiment, as it affects not only their physical presence but also cooperation [Mataric et al. 2007]. Fong (2003) classifies social robots' embodiment in four broad categories: anthropomorphic, zoomorphic, caricatured, and functional.

However, some studies have compared physical robots with computer agents and showed differences in the users' perception. In a study with 113 participants comparing a collocated robot, a robot projected on a big screen and an agent on a computer screen, [Powers et al. 2007] showed that people liked the robot more than the agents. In addition, they observed that the kind of robot to be chosen depends on the task to be executed.

Literature shows that even the very simple machines with life-like form or movement are associated with goals, emotions, personalities and objectives by humans [Tapus et al. 2007]. This anthropomorphism, however, is usually said to be necessary for a meaningful social interaction [Fong et al. 2003], as robots should interact with humans in a similar way as that of humans interacting with humans.

Li (2010) used an anthropomorphic, a zoomorphic and a functional (machine-like) robot in their study. They found significant differences in the attitude towards these robots from people with different backgrounds. Nonetheless, they state that even slightly humanoid features might be enough to increase people's familiarity to robots and therefore result in an elevated likeability. Yet, [Robins et al. 2004] showed that autistic children initially preferred a robot with its plain robotic appearance over a robotic doll dressed like a human (a 'pretty doll' appearance).

These studies indicate that different groups of users have different perspectives and opinions towards the embodiment of robots, even though humanoid robots are usually preferred by most groups studied. Blind persons is one of the groups that have yet to be tested working closely with social robots and, thus, their perception needs further investigation.

Assistive robotics usually involves physical interaction. In the context of blind people's needs, robots could have their functional side combined with motivational ones, as the range of assistance options blind persons could get from a robot is enormous. However, in order to use robots to help the blind in social interaction-oriented tasks, it is necessary to understand the users' impressions towards these robots, as they might be different from those of sighted individuals.

3. Experiment

As blind persons face many challenges in their everyday lives, robots could be used to help them in a variety of different ways. However, before turning these assistive robots into socially assistive ones, we need to understand how the design issues in social robots research impacts robot-human interaction for the blind.

As one of the key role in the robot's assistive effectiveness [Tapus et al. 2007], we chose to analyze the physical embodiment of our agent, leaving aside other factors for future studies. As anthropomorphism is usually preferred when it comes to having a meaningful social interaction [Fong et al. 2003], we decided to use a physical collocated humanoid robot, a regular laptop, and to compare blind persons' reaction to them.

The objective of this experiment is to test whether the participants will prefer to interact with a robot, as it is anthropomorphically embodied, or with a laptop, which is only functionally embodied, after executing the same task with both. We designed an experiment with a within-subject study design, where the robot and the laptop helped blind participants to prepare a beverage through vocal instructions.

The robot and the laptop were able to identify the beverage the participant was holding, as well as being able to give instructions on how to operate a coffee machine. This is important, as only a sighted person can identify without assistance the capsules (or ”pods”) the machine uses for coffee making. Two sessions were conducted with each participant, in two different and non-consecutive days. In the first interaction, randomly-assigned participants interacted with the robot and the others with the computer. In the second interaction, those who interacted with the robot interacted with the computer and vice versa.

Our hypothesis are as follows:

- **H1:** Participants will prefer to interact with the robot;
- **H2:** Participants will perceive the robot as more naturalistically embodied than the computer;
- **H3:** Participants will perceive the robot as more alive than the computer;
- **H4:** Participants will perceive both systems as intelligent;
- **H5:** Participants will feel equally calm while using both systems;

3.1. The systems

We use the word *system* here meaning either the robot or the computer and all what is related to it during the experiment (e.g. coffee machine, voice recognition, etc).

3.1.1. The robot

The robotic agent used in our experiment was Revolution JD, from EZ Robot. It is a low-cost, 33 cm tall humanoid robot with 16 degrees of freedom. JD has a camera on its head and a built-in speaker. It is intended to be used as an entertainment device as well as an educational tool, allowing researchers to dynamically adapt it to their needs.

JD's camera can be used for different computer vision tasks, such as recognizing faces, objects and colors. JD connects wirelessly to a computer which processes all the information through its software platform.

Assistive robots must efficiently display natural communicative performance that is not only adequate but engaging to its users [Tapus et al. 2007]. Therefore, following the current trend in cloud robotics, we used cloud based services for voice recognition and text-to-speech. That allowed us to, without prior training, use a more natural voice and advanced speech recognition in the participants' language (Brazilian Portuguese in our case).

A script in JD's software had a set of predefined grammar and the system would ask the participant to repeat if it did not recognize what was said. The grammar was designed to guide the participant's answers. For example, if the system asked the participant whether they wanted more instructions or not, it would say ”Do you want more instructions? Please respond with yes or no.”

3.1.2. The computer

The computer used in our experiment was a regular laptop. Thus, the only significant difference compared to the robot was the embodiment itself, with the laptop's camera being used for recognition.

The idea behind this setting was to make both systems as similar as possible, leaving only the embodiment as a differing factor. The same softwares were used for voice and image recognition, and there was no difference in the wait time for recognition in either systems.

3.1.3. The coffee machine

Both systems helped the participant verbally by optionally giving instructions on how to operate the coffee machine but, most importantly, by recognizing what beverage the participant was holding. The coffee machine used in the experiment was a NESCAFÉ® Dolce Gusto®, which heats the water that is then passed at high pressure through a capsule of roasted ground coffee into the cup. It's a 15 bar system that uses pressure similar to coffee house machines, and each pod makes one beverage serving in under a minute [S.A. 2017]. However, neither the pods nor the original boxes come with braille information, so there's no way a blind individual can know what kind of beverage he/she is holding.

3.2. Method

3.2.1. Subjects

Participants were recruited by the staff at a non-governmental institution specialized in care and education for the blind. All participants were volunteers, gave their full consent, and were informed during the recruitment that they would be completing surveys and interacting with a small robot. Only people with congenital or acquired blindness were asked to participate. It was logistically difficult to acquire a large number of participants for the study. In fact, most studies with blind persons have a small number of participants (see [Gharpure and Kulyukin 2008] and [Mau et al. 2008]).

Although ten people took part on the first part of the study, a total of seven (N = 7) participants completed the whole experiment, ages ranging from 23 through 63. The other three participants could not get to the institution for the second part (reasons also included logistics problems).

3.2.2. Procedure

The participants' task was to autonomously prepare a beverage by only asking the robot for instructions.

On the first day, five people interacted with JD and two with the computer. One week later, they followed the same procedure, but the ones who had interacted with JD then completed the task with the help of the computer, and vice versa.

On the first interaction, each participant was brought into a room where they were welcomed by two researchers who discussed the experiment and the informed consent form. If the participant agreed to take part in the experiment, he/she was taught how to operate the coffee machine. Each participant sat at a table that had a computer, JD, the coffee machine and a little box with six randomly placed beverage pods, two from each flavor (the beverage options were espresso, coffee with milk, and chocolate milk). As the description of the robot might interfere in the user's perception of it [Min et al. 2015], participants had some time to freely touch the computer/JD and ask questions about their functionality.

One of the experimenters placed a plastic cup on the coffee machine at the beginning of the experiment and, later on, signaled when it was time for the participant to turn off the machine, as this specific version of the machine was not automated for this.

The participants were told that they could say ”let's start” (in their native language) and the system would answer. Once the participant said that, the script was triggered on the software platform and the system greeted them and briefly explained what it could do. It then asked the participant to choose from the three types of beverages. The software then waited for the participant's decision. As soon as the participant said to the system which beverage they wanted, the system would tell the participant to start picking pods from the box and to place them about ten inches away from its camera, moving it slowly back and forth as the system would recognize the kind of beverage.

As soon as the system recognized the beverage, it asked the participant if they wanted to choose another flavor. If the answer was yes, it would repeat the process of choosing the beverage. If the answer was no, the system would tell the participant to start preparing the beverage, following the instructions previously given by the experimenter on how to operate the coffee machine. The system also offered to give complementary instructions if the participant needed, and if the answer was yes, it would go through the process of preparing the beverage, step by step. Once the participant told the system the beverage was ready, it would warn the participant that the cup's content was hot, tell them to enjoy the beverage and wish them a nice day. This would also occur if the participant had said they did not need help.

3.3. Instruments

As soon as the interaction was over (i.e. the participant signaled that he/she had successfully prepared the beverage), each participant answered a series of questions. The questionnaire was based on the Godspeed series [Bartneck et al. 2009]. The exact same questionnaire was applied for both the first and second interactions. The only difference while asking the questions was on identifying the current system. For example, when the participant had interacted with the computer, the question *Please rate your impression of the robot on these scales* had the word *robot* replaced by *computer*, and so on.

Interviews were semi-structured as the participants were free to make observations about each answer if they wanted to. After each interaction, the same questions were made to each participant. At the end of the second interaction, the participants were asked if they preferred to interact with the robot, the computer, or if they liked both equally, and why they chose their answer.

Observations were made by one of the experimenters in the room in the form of notes. This was intended to help understand the aspects of the interaction, such as the participants gestures and reactions to either system.

4. Results

4.1. Robot vs. Computer

In order to test participants' answers, we used the Wilcoxon Signed-Rank Test. Many different tests are used in the general area of HRI, and as they all have different aspects, we had to analyze which one best suited our work. For example, in order to use the t-test of comparison between means of two paired samples, such samples must have normal distribution. As such assumption was violated in our study (confirmed by the Kolmogorov-Smirnov Normality test), the non-parametric Wilcoxon test was used. Bonferroni, another common test, is focused on multiple comparisons and it is used in Analysis of Variance (ANOVA), which, in turn, is also only used when the samples are normal. ANOVA compares means from three or more samples, which was not our case. Additionally, as we do not have many references to guide us on the specific topic of blind people using social robots, we followed methods used in the SAR area which also apply the Wilcoxon Signed-Rank test [Fasola and Mataric 2012].

The Fake/Natural question showed a statistically significant difference ($p < 0.05$), what supports Hypothesis 2, where we state that *participants will perceive the robot as more naturalistic embodied than the computer*. The other questions regarding **Anthropomorphism** were Machinelike/Humanlike ($M_C = 2.43$, $M_R = 3.86$), Artificial/Lifelike ($M_C = 3.14$, $M_R = 4.00$), and Unconscious/Conscious ($M_C = 3.71$, $M_R = 3.71$). These questions did not have significant statistical differences ($p > 0.05$).

In the **Animacy** part of the questionnaire, there was no statistical difference in the Dead/Alive question, so Hypothesis 3, *participants will perceive the robot as more alive than the computer*, cannot be supported. The questions here were Dead/Alive ($M_C = 4.00$, $M_R = 4.00$) and Apathetic/Responsive ($M_C = 4.00$, $M_R = 4.71$).

The **Likeability** questions were Dislike/Like ($M_C = 4.29$, $M_R = 5.00$), Unfriendly/Friendly ($M_C = 4.43$, $M_R = 5.00$), Unkind/Kind ($M_C = 4.71$, $M_R = 5.00$), Awful/Nice ($M_C = 4.71$, $M_R = 4.86$), and Unpleasant/Pleasant ($M_C = 4.86$, $M_R = 4.86$). This does not statistically support our Hypothesis 1, *participants will prefer to interact with the robot*, but as described in section 4.2, the qualitative answers suggest preference for the robot.

When considering the **Perceived Intelligence** of the systems, the ratings had no statistical difference, being sometimes higher for the robot and sometimes higher for the computer, supporting our Hypothesis 4, *participants will perceive both systems as intelligent*. The questions were Incompetent/Competent ($M_C = 3.86$, $M_R = 3.71$), Irresponsible/Responsible ($M_C = 4.43$, $M_R = 4.29$), Unintelligent/Intelligent ($M_C = 3.86$, $M_R = 4.57$), and Foolish/Sensible ($M_C = 4.14$, $M_R = 4.43$).

No statistical differences were found between the two systems for the **Perceived Safety** questionnaire which includes the emotional state of participants. Questions asked if participants were Anxious/Relaxed ($M_C = 5.00$, $M_R = 4.00$) and Agitated/Calm ($M_C = 4.86$, $M_R = 4.00$). This supports our Hypothesis 5, *participants will feel equally calm while using both systems*. However, the ratings were higher for the computer in this case, suggesting that the robot made the participants feel more anxious and agitated. Whether that is due to the novelty effect is unclear.

4.2. Preference

After the second interaction, when asked what system participants preferred, 3 participants (42.9%) said they preferred to interact with JD, 1 said to prefer the computer (14.3%), and 3 said to like both equally (42.9%).

When asked to explain their answers, the following statements were given[1].

4.2.1. Preference for the Robot

> **P1:** I preferred to interact with the robot because he[2] seems friendlier and has a body.

> **P5:** I preferred to interact with the robot because he seems more human and smarter.

4.2.2. Preference for the Computer

> **P2:** I prefer to interact with the computer because it is easier to carry around.

> **P2:** It would be interesting to have a rod to help identifying where the camera is on both systems, instead of having verbal instructions on how to locate it.

4.2.3. Both Equally Liked

> **P4:** As they both did the same, I like either. However, the robot is more beautiful, and I would like to have it at home. The robot also becomes more interesting because, you know, the computer is very common and everyone has one, but not a robot.

> **P7:** It made no difference due to the task, but I would prefer to interact with the robot on a daily basis. Robots seem easier to carry around.

If we consider that the task was deliberately intended to evoke the same feelings towards either system, the participants' answers support Hypothesis 1, where we say that *participants will prefer to interact with the robot*.This is supported by research in the SAR area (see 2). [Matarić et al. 2007] compared participants interaction with a physical robot, a remote physical robot seen through a screen, and a virtual robot. Participants found the physically present robot to be the most watchful and enjoyable of the three conditions.

[1]Freely translated.

[2]Unlike English, in Portuguese there's not such pronoun as "it" when referring to objects, so this is not to be seen as an indication that the participant is giving the robot a gender.

4.3. Discussion and Limitations

As an emerging field, socially assistive robotics has little published research to which we can compare our results, especially regarding blind users. In this section, we discuss our findings relative to the perception of users and observations made by them towards the embodiment and other aspects of the robot.

A robotic system has advantages over non-embodied agents regarding safety. In our experiment, we executed the same procedure for both systems, not using the full capacity of our humanoid robot, as we wanted to investigate if the physical embodiment played a role in the social interaction. Nonetheless, in the context of our experiment, the robot could have been able to retrieve the cup and to give it to the user only after it was safe for them to hold it, as P3 point out. This kind of functionality would certainly increase the users likeability towards the robot. All participants had the opportunity to ask the system for instructions on how to operate the coffee machine, but only participants P4, P6 and P7 used this feature. We noticed that they only asked this to JD. Even P4, who had already interacted with the computer during the first week, asked the robot.

All of these observations are very important for the future of socially assistive robotics. They bring ideas of how social robots could be used in order to help the blind as well as address more generic topics that, although researched in areas such as human-computer interaction, should be considered for the development of the interaction between robots and blind people.

Nevertheless, in our short term experiment, participants seemed to like JD more than the computer, engaging and showing more interest on it, though long term studies are needed in order to test whether this feeling remains or decreases over time.

5. Conclusion

In this paper, we investigated the perception of blind people towards a socially assistive humanoid robot. We found evidence that the robot's embodiment might be linked to the users' preference for it. SAR works with the most different kinds of special needs, and this study was developed keeping in mind that blind people might enjoy a social robot as much as a sighted person. This research is intended to shed light on the topic, contributing to the a brand new research topic.

Combining an appealing physical embodiment with social aspects in a robotic system designed for the blind may improve their lives in a variety of different ways. While the functional part of the robot can be used to help them with specific tasks, it may also improve their self-confidence (e.g., on doing tasks without having to ask other people), make them feel happier for having a companion and evoke other positive feelings, as well as motivating them to socialize more. To conclude, the physical presence of JD clearly had an impact on the users perception of it, but whether that is part of the novelty effect should be addressed on long-term studies.

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