Using Proxemics to Evaluate Human-Robot Interaction

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***Abstract*—Recent feasibility studies involving children with autism spectrum disorders (ASD) interacting with socially assistive robots have shown that children can have both positive and negative reactions to robots. These reactions can be readily identified by a human observer watching videos from an overhead camera. Our goal is to automate the process of such behavior analysis. This paper shows how a heuristic classifier can be used to discriminate between children that are attempting to interact socially with a robot and children that are not.**

***Index Terms*—HRI, autism spectrum disorders**

I. Introduction

This work is part of a larger effort to develop an autonomous socially assistive robot system for free-play interaction with children with autism spectrum disorders (ASD) [1]. Socially assistive robots (SAR) have been shown to have promise as potential assessment and therapeutic tools, because children with ASD express an interest in interacting socially with such machines [3, 4]. Our work is motivated by the fact that SAR may hold significant promise for ASD intervention. The long-term goal of this and related endeavors is to develop robot systems that can aid in the diagnosis or treatment of ASD.

The unconstrained nature of the free-play task used as part of ASD therapy is intended to engage children on a wide range of the autism spectrum, including lower-functioning children with less mature communication abilities. In human-robot implementations of the free-play task, the child and robot can interact however the child chooses, with no specific task or game rules or constraints. However, autonomous operation of the robot in such a free-form social setting presents a range of challenges, including understanding the social behavior that occurs during the experiment session in time to formulate appropriate real-time robot responses. In addition, the unconstrained nature of the interaction means that any *a priori* categorization of the child's behavior can be quickly and frequently confounded, especially considering the heterogeneous nature of the ASD population.

As part of our development of an autonomous robot for free-play settings, we aim to show that automatic behavior coding can be used to discriminate between children that are attempting to interact socially with a robot and children that are not. We present results using data from a pilot study involving eight children with ASD.

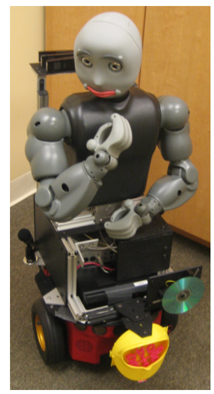

Fig. 1. The humanoid robot used in the experiment.

II. Methods

We conducted a feasibility study with human subject participants that provided the data reported here. The study consisted of a free-play scenario involving a robot, a child, and a parent. The recruited children were all diagnosed with ASD. The robot moved autonomously around the room, was able to gesture, make non-verbal vocalizations, and blow bubbles.

A. Robot Behavior

The autonomous behavior of the robot was programmed to encourage social interaction. For example, when the child approached it, the robot nodded its head and made an encouraging vocalization. When the child moved away, the robot acted disappointed by moving its head down and making a sad-sounding vocalization. When the child pressed the button on the robot, or vocalized to the robot, the robot blew bubbles and turned in place. When the child was behind it, the robot ignored the child, thereby giving the child the opportunity to hide/separate from the robot. As much as possible, the robot oriented itself to face the child, and approached the child when s/he was far away ($>$ 1m). In all cases, the robot ignored the parent, except to avoid him/her as an obstacle.

B. Data Collection

We recorded audio and video from eye-level cameras mounted in the corners of the room as well as an overhead

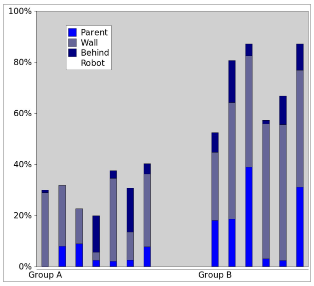

Fig. 2. Proxemic states for children that had a positive reaction to the robot (Group A, left), and those that had a negative reaction to the robot (Group B, right). Group A spent less time near the walls, the parent, or behind the robot.

camera in the center of the room pointed straight down, and cameras mounted in the eyes of the robot. Of these cameras, the eye-level cameras were used by the human data coders, and the overhead camera was used for the automatic coding.

A total of 100 minutes of experiment time was recorded over all sessions with all participants, 60 of those involving human-robot interaction and the rest involving interaction with a non-robotic toy. After a preliminary data coding, several observations were made regarding how children reacted to the robot. Some children had a positive impression of the robot and made several attempts to engage the robot socially. In particular, these children played with the robot when it blew bubbles and spoke to it in order to encourage it to socially interact with them. Some children beckoned the robot to follow them around the room. In contrast, some children had a negative reaction to the robot. Negative reactions ranged from avoiding the robot, to backing up against the walls of the experiment space, to seeking comfort from the parent.

C. *Heuristic Data Analysis and Results*

We used the recorded video data and markers on the parent and the robot to determine the positions of the parent and child in the room as well as the position and orientation of the robot [2]. These data were used to automatically annotate the videos. Given that children who had a negative reaction to the robot spent a good deal of time near the walls of the room, near the parent, or behind the robot, we aimed to automatically detect those features.

We used the following heuristics to automatically annotate the data. For each slice of time, if the child was within $.85$ meters of the parent, the system observed the child as being near the parent; if the child was within 0.5 meters of the wall, the system would record an observation of being near the wall; finally if the child was behind the robot at any distance (greater than 135° or less than -135° from the front of the robot) the system would record a behind the robot observation.

We grouped the recorded sessions into two groups. Group A ($n = 7$) consisted of the sessions with children who liked the robot and spent a significant amount of time interacting and playing with it. Group B ($n = 6$) consisted of the sessions with children who did not like the robot and spent a significant amount of time avoiding it and/or seeking comfort from their parent. When we compared the percentage of session time that the automatic system annotated that the child was either near the wall, near the parent, or behind the robot for Group A and Group B, we observed that all sessions in Group A had these observations less than 40% (mean 30%, stdev 0.07) of the time, while Group B had these observations greater than 50% (mean 71.9%, stdev 0.15) of the time, a clear discrimination between the two groups. With these results, a classifier could easily be constructed based on this percentage, greater than 50% time spent in the negative behaviors would indicate a session where the child was not trying to interact socially with the robot, while less than 50% would indicate that the child was attempting to interact socially with the robot.

III. Discussion and Future Work

This work shows that automatic data coding can be used to discriminate between children that are attempting to interact socially with a robot and children that are not. We used an overhead camera system and automatic observations based on heuristics to determine the activity occurring during the session. These results support further investigation into the use of our overhead camera system to make determinations about what occurred during an experiment session.

However, since these results are based on human-determined heuristics, the scalability and generalizability of this method comes into question. Future work will investigate the feasibility of using less supervised methods of coding the data for making accurate observations. In addition, the small number of children in the reported pilot study makes it difficult to show how this method would perform on a larger and more varied sample.

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