Towards the integration of socially assistive robots into the lives of children with ASD

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1. INTRODUCTION

Socially Assistive Robotics (SAR) focuses on providing aid to the user through social rather than physical interaction [2]. SAR has a broad range of possible application domains. One particularly promising area is the use of SAR as a tool for assessment and therapy for children with autism spectrum disorders (ASD), because these children have been shown to express an interest in interacting socially with robots [6, 8]. Our work is specifically motivated by the fact that SAR may hold significant promise for helping children with ASD develop richer social skills through interactions with social robots. Our long-term goal is to develop robot systems that can help children with ASD in their daily lives and improve their abilities to socialize.

Our approach utilizes feasibility studies (to determine if a socially interactive robot can behave appropriately in experimental settings), and behavioral studies (to verify hypotheses regarding properties of the robot that facilitate improved social interaction for users with ASD). In the next section, we briefly summarize related work. Then, we describe our robot system used in the studies. Next, we describe performance metrics, ethical issues, and a plan for integrating such an experimental SAR system into the daily lives of children with ASD.

2. RELATED WORK

Compelling evidence has shown that a robot may encourage social behavior that chilren with ASD do not normally exhibit with other people or toys [9, 10]. Most encouraging is the observation that a child with ASD engages in more proactive social behavior [1] (behavior initiatiated by the child, a deficiency for children with ASD) in such contexts. This raises the possibility that a social robot might be usable in diagnosis [8] and/or treament [1] of children with ASD. To explore these possibilities, robotics researchers are using robots in social, educational, and examination settings and exploring how children with ASD interact with them [4, 7].

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While there is promise that a social robotic character will provoke and encourage proactive social behavior [1], there is also potential that a robot could be distracting for a child, detracting from existing therapies. Taking this concern into account, we aim to design SAR systems that can be integrated into therpeutic interventions currently used for ASD treatment. In particular, we wish to explore the possibility that a social robot will promote both human-human and human-robot interaction.

A great deal of work that pairs robots with children with ASD involves tele-operation or pre-programmed behavior [7, 4, 8], where the robot is either being driven by a human remotely or merely playing a stock series of actions. This approach requires far less in the way of robot sensing and control design for effective operation because the operator provides those facilities. However, it has serious drawbacks. First, it is impossible to separate the effects of the operator puppeteering the robot from the role of the robot. Next, it is impossible to tell how different a real robot might behave, based on real sensing and autonomous control, in a similar setting. Thus, one of the chief goals of this work is to develop and assess the impact of autonomous socially assistive robots for interacting with children with ASD.

3. EXPERIMENT SCENARIO

While there is evidence that the presence of a robot has an effect on a child's social behavior, there are no data yet on whether the behavior or morphology of the robot itself has an effect on the child. Therefore, one aim of our research is to determine if the behavior of the robot has an effect on the social behavior of the child. Our current work involves using several configurations of a robot system (embodied/non-embodied, anthropomorphic/non-anthropomorphic, contingent behavior/random behavior) in order to determine the optimum configuration for encouraging social behavior.

We developed an experimental scenario to test these comparisons that is also suitable for evaluating the performance of the robot. The scenario we selected is based on the use of bubbles as part of standard ASD diagnosis. We developed Bubble Play, a computer-controlled bubble-blower that can be mounted on the robot, and equipped the robot with two large colorful buttons, as shown in Figure 1(b). The robot responds to a child's actions, with movement, bubble blowing, and sounds. Other planned scenarios that can be used to test these comparisons include Hide & Seek, Simon-Says, and other imitation games.

The intended role of the robot in this case is as a catalyst for social interaction, both human-robot and human-human, thus aiding human-human socialization of children with ASD, rather than as a teacher for a specific social skill. This allows for the scenario where the robot is not specifically generating social behavior or participating in social interaction, but instead where robot behaves in a way known to provoke social interaction. The Bubble Play scenario was designed to facilitate (and encourage) just such interaction. Bubble play, when performed by a human companion (therapist or parent), is known to provoke social interaction between the child and the person operating the bubble blower [5]. Thus using the robot as a substitute is ideally suited for evaluating the specific social effect of the robot, and its potential for use in therapeutic settings.

3.1 Experimental Validation

We have conducted a feasibility study with children with ASD in order to verify that the robot could be effective as part of the described scenario. Our priority was to demonstrate that the robot's behavior has an effect on the child. In addition, we explored the effect that a contingent robot (one that acts in response to the child's actions) has on his/her social behavior. Finally, we wished to demonstrate that the robot can observe (and potentially analyze) collected social interaction data as a necessary prerequisite for more complex autonomous social behavior. By having the parent and the robot (or toy) in the room, we could measure changes in human-human and human-robot interaction.

As described above, the purpose of the validation experiment was to determine whether or not the robot's social behavior has an effect on the child's social behavior. To test the hypothesis, we created two experimental conditions, *contingent* and *random*. During the contingent condition, the robot faced the child.

In the *contingent* condition, when the child pushed a button on the robot, it turned in place and blew bubbles. In the *random* condition, the robot blew bubbles at random intervals and not in response to the child's actions. No specific robot response followed the pressing of the button.

If there were a measurable difference between the contingent and random conditions, then the hypothesis that the behavior of the robot has an effect on the resulting social behavior of the child is supported in those conditions. If the contingent condition elicited more social interaction than the random condition, we could infer that the robot behaving contingently with the child would be more effective as part of an intervention than a randomly behaving robot. For the feasibility study, we recruited four participants (3 ASD, 1 typically developing) ranging in age from 20 months to 12 years old. The feasibility study produced a series of qualitative and quantitative observations of the child's social skills, which included vocalizations, initiation of behavior, social orienting, and pointing.

3.2 Performance Metrics

During each experimental session, video data were collected and subsequently annotated by a human observer, coding for the following specific social behaviors:

- Speech/vocalizations
- Gestures (pointing, waving, etc.)
- Movement toward/away from/in front of person/robot
- ASD-stereotypical behavior (hand flapping, etc.)
- Joint attention/eye contact with parent/robot
- Actions to control robot (button pushes, moving to make the robot move)

For each presentation we annotated the video recordings for the above behaviors, including the target social behavior as well as whether the behavior is proactive or in response to the parent or robot. We then computed the quantity of the coded interactions interactions. We compared quantity values between conditions.

3.3 Proposed Experiment Design

Our ongoing work is preparing expanded experiments on more sophisticated robot platforms. Specifically, we are using a child-sized humanoid torso mounted on a mobile platform, which is more obviously capable of displaying social behavior, through the use of facial expressions, gestures, head movements, and body movements. We are also working on a multi-session experimental design to determine the effects of repeated exposure. All participating children will be administered cognitive and social evaluations once before these sessions and then after the conclusion of all sessions. We are currently working with ASD experts to prepare evaluations that can be conducted in this experimental framework.

Our experimental performance metrics will be two-fold. Using the data that we collect in-session, we will be able to compare a child's social behavior between sessions. Our first set of performance metrics is the change in a user's social behavior between two sessions, the change in proactive social behavior, and the change in human-human behavior between sessions. Using the social and cognitive evaluations done before and after the sessions with the robot, we will be able to evaluate the impact of the robot on the child's behavior and any changes in a child's behavior between the evaluations.

4. ETHICAL ISSUES

Ethical considerations are paramount in assistive technologies. It is crucial that an assistive device does good without doing harm. Perhaps the largest ethical concern with robots for children with ASD is that if these children do interact with robots better than they are able to with other people, social robots could be used to replace, rather than enhance, human social contact. If this were to occur, a robot may be an impediment to the socialization of children with ASD.

Since our goal to use robots as tools for human-human socialization, we take this concern very seriously, and use two approaches to guard against undesirable effects. First, we designed our metrics in order to observe both human-human and human-robot interaction. This allows us to determine the relationship and influence of human-robot interaction on

(a) Robot used in the experiments (b) Interaction with the robot

Figure 1: The robot in an experimental setting.

human-human interaction, both in-session and between sessions. Second, we have made the amount of additional/new human-human interaction that results when a child spends time with the robot our chief performance metric for our assistive robot system. Thus success for our work amounts to increases in human-human not human-robot interaction.

Another ethical concern about involving technology in behavioral therapy is that short-term gains in instantaneous measures may be confused with long-term progress and adequate care. A robot that makes a child behave more socially during a thirty-minute experimental session does not mean that the child will behave more socially in the long term. This is a general challenge of behavioral therapy, well beyond the scope of the use of technology. It mandates that all efforts present results as accurately as possible so that real effects, and their limitations, are clear.

5. INTEGRATION INTO DAILY LIVES

Developing and evaluating technologies for ASD is a promising and satisfying area of research. However, it is still limited to the confines of highly controlled experimental settings, in two ways. First, we control the environment that the robot operates. This is done for several reasons, including enabling the robot to effectively sense its surroundings and to act and react safely, and recording data for analysis. Second, we plan to constrain our participant population by age (5-10 chronological years of age) and by verbal ability (able to speak small phrases or better) in order to work with a more homogeneous participant cohort. To integrate an assistive robot into the lives of children with ASD, it will be paramount to move from highly controlled environments into natural everyday settings, and to make the robot personalizable.

Our ongoing work involves the development of a sophisticated humanoid robot system that operates in a sensor-equipped smart space at Childrens Hospital Los Angeles, part of the Boone-Fetter Clinic for children with ASD [3]. While we are developing systems that can operate in similarly augmented clinic spaces, our longer-term goal is to develop SAR systems capable of operating in places where children spend most of their time: schools and homes. The home is the best environment for long-term therapeutic interaction, but as homes vary tremendously, the challenges to robot perception, control, and safety are greatest there, and are part of the larger robotics research thrust toward in-home service robots. Additionally, to make the technology broadly useful, its cost must be reduced to to levels that a typical family could afford.

To make our robot system work for a wider range of children with ASD (verbal ability, age, etc.), we are also developing means to personalize the robot's behavior. Personalization will address the large degree of behavior and symptom heterogeneity present in the ASD population. Some children prefer auditory communication, while others prefer gestures; some need a significant number of social actions in order to provoke behavior, others are intimidated by the same actions. We are working to present such customization of the SAR system for therapeutic uses in a human-readable format suitable for non-technical therapist use.

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