A Pilot Study for a Robot-Mediated Listening Comprehension Intervention for Children with ASD

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Abstract— Autism spectrum disorder (ASD) is a life-long developmental condition which affects an individual’s ability to communicate and relate to others. Despite such challenges, early intervention during childhood development has shown to have positive long-term benefits for individuals with ASD. Namely, early childhood development of communicative speech skills has shown to improve future literacy and academic achievement. However, the delivery of such interventions is often time-consuming. Socially assistive robots are a potential strategic technology which could help support intervention delivery for children with ASD and increase the number of individuals that healthcare professionals can positively impact. In this work, we present a pilot study to evaluate the efficacy of a robot-mediated listening comprehension intervention for children with ASD.

I. INTRODUCTION

The Center for Disease Control estimates that 1 in 59 children have autism spectrum disorder (ASD) in the United States [1][2]. ASD is a life-long developmental condition that affects an individual’s capability to communicate and relate to others. The field of Applied Behavioral Analysis (ABA) is a scientifically proven treatment for the behaviors that inhibit communication in these populations [3]. Discrete Trial Training (DTT) is an application of the principles of ABA in a structured teaching environment to teach behaviors (e.g. social, educational, physical). Namely, DTT involves providing clear instruction of a targeted behavior by breaking it down into a set of skills and systematically teaching these skills one by one via positive reinforcement for correct responses. Such methods require significant time from healthcare professionals, which can limit the number of individuals that healthcare professionals can positively impact.

Socially assistive robots could be a supportive technology to these healthcare professionals as they provide care to individuals with autism. Numerous socially assistive robots have been already developed and utilized for interventions targeted towards individuals with ASD. Some applications of these robots for individuals with ASD have included: 1) imitation therapy [4], [5], 2) improving social skills (e.g. turn taking, joint attention, eye gaze, greetings/goodbyes) [6], [7], 3) encouraging self-initiated social interactions [4], [8], [9], 4) reducing challenging behaviors [10], [11], and 5) improving emotion recognition [11], [12]. In general, these robot-mediated intervention scenarios have had positive outcomes with behavioral-based changes for individuals with ASD. To date, research in robot-mediated interventions for individuals with ASD have had minimal focus on academic objectives [13].

In this work, we present a pilot robot-mediated DTT-based listening comprehension intervention for children 3-8 years old with ASD. We have chosen a listening comprehension intervention because early childhood education on communicative speech skills has been shown to be one of the most important factors for positive long-term quality of life for individuals with ASD [14]. Namely, the ability to answer wh-questions is one of the most important communicative skills in early childhood education.

II. ROBOT-MEDIATED LISTENING COMPREHENSION INTERVENTION

The goal of the intervention is to improve the listening comprehension of a child with ASD. The intervention consists of a robot mediator reading passages from electronic books (e-books) and asking the child wh-questions with the aim of fading prompts until the child can independently as well as correctly answer wh-questions.

A. Humanoid Nao Robot

The humanoid Nao robot, Figure 1, stands 58cm in height with two degrees of freedom (DOF) in the head, five DOF in each arm, one DOF in each hand, and six DOF in each leg to enable and produce physical movements. Nao can speak verbally through speakers. Furthermore, it has seven touch sensors, four bidirectional microphones, and two 2D cameras allowing the robot to sense the environment around itself. The robot can also be controlled remotely via a Wi-Fi connection.

Figure 1. The Humanoid Nao Robot

B. E-Book

Our team has designed e-books for the robot mediator to use during our interventions. It has been designed specifically for teaching wh-questions and answering for children. The e-book is accessible via a web browser and has a page turning animation like a physical book. The motivation for this is to mimic as closely as possible a human-based intervention. Pages can simply be turned by clicking on the page of a book or swiping your finger across a tablet screen. On each page of the book is a picture of an animal with a sentence consisting
of a main subject performing an action in a location. For example, Katie the cat was sitting on the coach. The illustration will be a digital image of the main subject within a neutral background without any animations. An example page in the book is shown in Figure 2.

Figure 2. Sample pages from the e-book

C. Intervention Setting

The intervention took place at the Oakland University Applied Behavior Analysis Clinic within a private therapy room approximately 8’ x 10’ in size with carpeted floor, Figure 3. The room has a table and four chairs. The robot mediator sits or stands across from the child to conduct the intervention. A computer monitor on the table presents the e-book to the child and the robot mediator refers to the e-book throughout the intervention. A behavior technician was always present in the room to keep the child physically interacting with the robot, to help keep the child seated in a chair in front of the robot, and to collect data. A video camera was also placed in the room to record the interaction for post-study analysis. During the robot-mediated interventions a researcher was controlling the actions of the robot during the intervention and collected data to ensure interobserver reliability.

Figure 3 Intervention Setting

D. Intervention

Each intervention session begins with the robot-mediator introducing itself and notifying the child that they will be reading together during the session. The robot will then read through the entire book (3 pages) while requesting the child to answer wh-questions after each page. Namely, after the robot has read over one page and displayed the illustration to the child he/she will be asked a wh-question. Wh-questions included only who, what, and where questions. Questions were structured as follows; 1) “Who was (action)?”, 2) “What is (noun) doing?” and 3) “Where did (noun perform an action)?”. See Table 1 for the questions used during the intervention.

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Sample Question</th>
</tr>
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<tbody>
<tr>
<td>sub-skill (who)</td>
<td>Who was sitting on the coach?</td>
</tr>
<tr>
<td></td>
<td>Who was chasing their tale?</td>
</tr>
<tr>
<td></td>
<td>Who was slithering on the ground?</td>
</tr>
<tr>
<td>sub-skill (what)</td>
<td>What is Katie the cat doing?</td>
</tr>
<tr>
<td></td>
<td>What is Doug the dog doing?</td>
</tr>
<tr>
<td></td>
<td>What is Sam the snake doing?</td>
</tr>
<tr>
<td>sub-skill (where)</td>
<td>Where did Katie the cat sit?</td>
</tr>
<tr>
<td></td>
<td>Where did Doug the dog chase his tail?</td>
</tr>
<tr>
<td></td>
<td>Where did Sam the snake slithering?</td>
</tr>
</tbody>
</table>

A time delay prompting protocol was used based on a child’s prior performance to wh-questions. A prompt is supplemental stimulus that increases the probability of a correct response. There are three levels of prompts before a child achieves skill independence. These levels include: 1) an immediate prompt, 2) a 2-second delay before a prompt, or 3) no prompt. A child always begins at a level 1 prompt and the opportunity to independently respond gradually increases with each prompt level. The prompt level increases by one if they answer 8 out of the 9 wh-questions correctly for two consecutive intervention sessions. A child has achieved mastery only when they can answer 8 out of the 9 wh-questions correctly for two consecutive intervention sessions with no prompts.

III. Pilot Study

We conducted a preliminary pilot study of the robot-mediated listening comprehension intervention to investigate the performance of the robot-mediated intervention for teaching wh-questions to children with ASD.

A. Participants

The inclusion criteria for these participants were: 1) 3-8 years old, 2) DSM-4 diagnosis, 3) have not mastered wh-questions, and 4) can follow 1-step gross motor instructions. A total of two children from the Applied Behavior Analysis Clinic at Oakland University participated in our pilot study. Participant one was four years old and male. Participant two was five years old and female. Prior to initiating the intervention written informed consent was obtained from the participants’ parental guardians.

B. Procedure

The intervention was conducted over two months with each child participating in an intervention session 3-5 times a week according to schedule availability and only once per a day. Each session was 30-45 minutes depending on the performance and preferences of the participants. Namely, participants could request to end the session at any time. A typical session will include presenting a maximum of 27 wh-questions (who, what, where) with short breaks after the presentation of 9 questions. The selection of who, what, and where questions were randomized but in total each type of question was presented 9 times per a session.

C. Data Collection

Data was collected by a researcher on the participants’ performance on answering wh-questions during the robot-mediated intervention. Namely, a plus (“+”) was recorded for
a correct response without a prompt, a plus p (“+p”) for a correct response after a prompt, a minus (“−”) for an incorrect response without a prompt, and a minus p (“−p”) for an incorrect response after a prompt. Data was collected by both the behavior technician and a researcher to ensure interobserver agreement.

D. Results & Discussion

Figure 4 and 5 shows the participants’ percent of correct responses with and without prompts over the course of the intervention sessions. Participant one took nine sessions to complete prompt level one (i.e. immediate prompt), three sessions to complete prompt level two (i.e. 2-second delay before a prompt), and two sessions to complete prompt level three (i.e. no prompt). In total it took fourteen session before participant one achieved complete mastery of the wh-question answering skill. Furthermore, we had three additional sessions with participant one which showed that he retained the mastery of the skill.

Participant two took sixteen sessions to complete prompt level one and two sessions to complete prompt level two. As of writing of this paper, participant two is still participating in the intervention at prompt level three and has participated in seven sessions at this prompt level. In total, participant two has participated in twenty-five intervention sessions. For this participant, a customization was made to improve the intervention because initially participant two was not responding to the robot’s immediate prompts. After two sessions, the behavioral technicians suggested that a human-like voice may improve the participant’s response to the robot’s prompts, so a modification was made to instead use a pre-recorded human voice on the robot. As can be seen from the results after the modification of the prompts to include a pre-recorded human voice the child immediately started to respond correctly to prompts. We hypothesize that participant two preferred a human voice over a synthetic voice because he/she was more familiar with human voices and perceived it as a stronger reinforcer. Similar preferences towards more human-like voices over synthetic voices have been observed with different populations of users [15], [16]. In future work, we plan to compare the differences between a pre-recorded human voice to a synthesized robot voice to see their effects on the intervention delivery for children with ASD. Furthermore, as the intervention has progressed the behavioral technicians have also suggested that more intermediary prompts may be necessary before participant two can reach complete mastery of the skill. Hence, we are presently exploring the development of intermediary prompts.

Figure 4. Participant one performance during the intervention sessions

Figure 5. Participant two performance during the intervention sessions

Overall, the participants are all improving in their capability to answer wh-questions over the sessions with prompts from the robot but only one participant has achieved mastery to date. Such differences in success are expected because children with ASD often require customized intervention plans due to their differences in capabilities and preferences [3]. With the insights gained form this pilot study, we intend on modifying our intervention to address the aforementioned challenges that have arisen with participant two and perform a systematic evaluation of the intervention with more participants.

REFERENCES


