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Robot Assisted Play for Children with Disabilities

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ABSTRACT

Children learn through interacting with their environment. Most children develop their cognitive and linguistic abilities though play interactions. The Lego Mindstorms Robotic Invention System™ is a tool that children with physical disabilities can use to facilitate play interactions. Over a four week period, a single participant learned how to use two Lego Mindstorms robots in play activities. The subject was able to achieve planned control over the robots by using head-mounted switches and a switch-adapted remote control. The subject demonstrated quick learning with various types of interactive play activities. The Lego Mindstorms Robotic Invention System was found to be a valuable tool for observing how children with physical disabilities can learn through play interactions.

KEY WORDS

Robotics, Play, Physical Disabilities, Children, Cognitive Development

BACKGROUND

Children who are unable to independently manipulate objects due to physical disabilities often cannot engage in the same play activities as their able-bodied peers. As a result, children with disabilities may have difficulty developing the cognitive and linguistic skills that typically developing children learn through play. Assistive technology for computer access, augmentative communication, and environmental control can be used to modify, or provide alternatives to, traditional object manipulation play activities. Robots have been used with very young (7 to 9 month) children (1), and with children with severe disabilities for self care tasks (2), elementary classroom activities (3), science instruction at the elementary school level (4) and general classroom use (5). We have also demonstrated that robotic systems can allow children with severe disabilities to develop and demonstrate cognitive skills that are typically learned through activities involving direct object manipulation (6). However, these studies were conducted with an expensive robotic manipulator that makes wide spread replication difficult. The purpose of this study was to explore the feasibility of using the widely-available and inexpensive Lego Mindstorms Robots for robot-enabled play activities.

RESEARCH QUESTION

Can the Lego Mindstorms Robotic Invention System™ be used to facilitate play activities for children who have physical disabilities?

METHOD

The investigative team used Lego MindStorms components to construct two robots; the roverbot (see figure 1) and a robotic arm (see figure 2). The initial design for the robotic arm included two motors; one motor fro base rotation and for arm elevation while closing or opening the hand simultaneously. The robotic arm was redesigned so that hand closure was separated form arm elevation and powered by a third motor. The Lego MindStorms system includes a remote control that either activate a programmed sequence of motor and sensor commands or controlled a motor function of the robot. The remote control was adapted to allow for switches to be used in place of each remote button. This allowed the child to press a large 7 cm switch with his head to activate the robot.

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The participant was an eight-year old with severe physical disabilities who used his head to activate the switches. Prior to the beginning the study, he had only used one switch, mounted to the right of his head for controlling battery-powered toys. During the study, the child was seen 2 times per week, for approximately 15-20 minutes, for a total of 8 sessions. Five of these sessions were videotaped. The sessions were conducted in the child's school facility. Before each session, the experimenters downloaded play-based programs into the robot for the child to use during the session and modeled the task for the child. If the child did not engage in the play task, a prompt hierarchy was followed: (1) full physical prompt + verbal (ie. investigator hand over child's hand), (2) partial physical prompt + verbal (ie. investigator's finger tip touching child's hand), (3) verbal prompt, and (4) visual (gesture) prompt.

The child completed a variety of tasks each day. The participant's teacher was interviewed prior to beginning the study to identify appropriately engaging and motivating tasks for the child. Roverbot tasks included: (1) hitting a switch to activate a song and dance program, and (2) holding down a switch to move the roverbot forward in order to knock over a tower of blocks. Robotic arm tasks were: (1) hitting a switch to drop a variety of toys, (2) hitting a switch to lift a toy into sight (3) hitting one switch to rotate the arm closer to the participant, followed by hitting a second switch to open the hand and release a toy, and (4) using one switch to lift an object into sight, and a second switch to open the hand and release the object.

RSULTS

The child quickly mastered initial play tasks that used the rovorbot controlled with a single right-mounted head switch. The child pressed the right side switch to carry out the initial roverbot tasks, but after he had mastered the tasks, he would often begin to display off-task behavior. At that point an additional step in the task or an entirely different and more complicated task was introduced. A second switch was introduced on the left side of the participant's head. The child's teacher reported that the child had not had any previous success with the left head switch. When the second (left) switch was introduced, the child displayed more goal-directed behavior since he had to press one switch before the other to complete a multi-step task. Also, at times, the child would have to hold down one switch for a specific period of time while monitoring the effect the switch press had on the robot; this would orient the arm at a specific position to be ready for the second switch press. The child would often gaze shift between the experimenters and play tasks, especially when he had just learned a new play task. All results were obtained from analyzing video of the experiment.

The child progressed through the play tasks rapidly and was able to easily complete them after a few trials. He child also quickly shifted his gaze between the investigative team, the robots and play tasks. He displayed much non-verbal communication during the play tasks. When the child the investigators was brought into the room with the robots, he vocalized and made eye contact with the investigators in a joyful manner.

The child's affect and attention changed throughout the course of the study. Initially, the child displayed flat affect and little attention towards the investigative team, robots, and play tasks. As the study progressed, the child smiled, displayed joint attention and vocalized. He also attended to the robots and play tasks more vigilantly, for a greater length of time and attempted more trials of the play tasks. The child required fewer prompts to carry out the play tasks as he learned the tasks, made fewer errors, carried out the tasks quicker, and consistently attended to the robots, tasks and investigative team. He also was able to complete a task he had learned the previous session with no prompting. As he learned more tasks, he learned new tasks quicker and with fewer errors.

At the end of the study, the participant's teacher was interviewed to determine if she had noticed any changes in the child's behavior, social skills, language, and/or academic skills during the robot study. She commented that prior to beginning the study the child had never used two switches. This is now a school goal for him. The teacher also noted that the child had started to remember concepts from the beginning of the year during the course of the robot study. She was not sure if using the robot had helped improve the child's memory, but thought that these events might have been related. When asked about the child's social skills, the teacher commented that she saw a difference in the child's behavior towards the researchers, but did not notice changes with others in the child's life. Specifically, the teacher commented that the participant smiled when he heard that the researchers were coming, and that he became more willing to do what the researchers asked of him throughout the course of the study. The teacher also commented that the child had become more vocal in the last few months – but she was not sure whether or not that was an effect of the study. She also commented that it was nice to see him being able to play independently as this was previously not a regular occurrence for him, and that she thought he enjoyed playing with the robots.

DISCUSSION

The results obtained from the data analysis of video, show how the child learned the play tasks with ease and enjoyment, leading the experimenters to conclude that the Lego Mindstorms robotic system was an excellent tool to facilitate play and learning activities for children with physical disabilities. The participant displayed rapid and active learning, which was a change in the more common passive play activities that were available to him. He also displayed strong memory skills by demonstrating knowledge of input required on tasks that had been previously done. The participant showed his understanding of the tasks to be carried out by pressing the switches in the correct order, for the correct length of time and by gaze shifting in anticipation. The participant's almost continual positive affect and gaze shifting between the task and the experimenters were displays of positive joint attention. Joint attention is a precursor to language development. The participant's continual display of excited joint attention leads to the conclusion that this type of robot play would facilitate language development.

The subject was very successful using the first switch. His ability to progress though the play tasks with the single switch and the roverbot at such a rapid rate was precursor to the experimenter's decision to introduce the second switch. The child was able to use the second switch very well and almost appeared to welcome the challenges that were presented to him. This is consistent with the teacher's report that the child appeared to

enjoy playing with the investigators and robots and was previously more passive in play activities. The child displayed behavior consistent with learning and memory throughout the study and this was verified by the teacher's comments.

Overall, the Lego Mindstorms robots were an excellent way to facilitate play activities for the subject in this pilot study. The child enjoyed himself, learned new play skills and displayed increased memory abilities

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Acknowledgements: Joanne Volden and Johanna Darrah contributed valuable insights for this study. Supported by: Stollery Children's Health Foundation, Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, Glenrose Rehabilitation Hospital, Edmonton, Alberta

Figure 1. The roverbot.

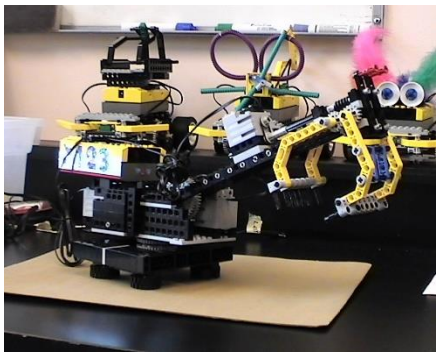

Figure 2. The robotic arm.