INTRODUCTION

Research has shown that children with severe disabilities who use robots can exert control over play activities, demonstrate cognitive skills not measurable with standardized tests, and appear more capable to teachers who witness students' success with robotic control (Cook *et al.*, 2005; Cook *et al.*, 1990; Cook *et al.*, 2002). Recent robot studies utilized a switch adapted infrared (IR) controller to allow play activities with inexpensive Lego[1] robots (Cook *et al.*, 2007). Using the built-in IR capability of speech generating communication devices (SGDs) to control toys "offers highly motivating activities for use in the development of language" (e.g., "come" "go", "in" "out")(Anderson, 2002, p. 7). Two results in the robot studies have shown the need to integrate robotic play with augmentative communication. First, an increased number of vocalizations during and after robotic intervention was observed in children who were emerging communicators. Second, if a child had a communication device, it had to be removed in order to access the robot controller, resulting in missed communication opportunities. For example, a participant accessing robotic control instead of her SGD strayed from the pre-planned robot play activity, ignoring prompts from investigators. Luckily, the participant's mother interpreted the child's non-verbal intentional behavior for the investigators. If the mother had not been there, the investigators would have missed the participant's communicative bid for innovative play. This example demonstrates a problem with typical SGDs, that children have to disengage from play in order to communicate and vice-versa (Light & Drager, 2002). Controlling robots through an SGD would provide an integrated and rich play environment which may contribute to the development of children's physical, cognitive, and communicative skills.

PURPOSE

The purpose of this project was to use a SGD to replicate the intervention protocol used in switch controlled Lego robotic play studies. Robot use for operational, communicative, and academic goals was investigated. Since the participant's classmates were using Lego robots in their science curriculum, engagement in school curriculum and interaction with classmates was also investigated. This paper focuses on the operational and communicative goals.

METHODS

This is a single participant case study. The participant was a 12 year old girl who has cerebral palsy with severe physical and communication limitations. She uses an SGD with which she had approximately seven months experience. She accessed the device with two switch step row-column scanning, with one switch on each side of her head.

Goal Attainment Scaling was used to measure intervention effect on goals (Schlosser, 2004). Goals and scaling were developed by the investigators, the special education teacher and members of a local assistive technology team. The participant approved the final goals.

For the operational goal, the participant maneuvered the roverbot (with a pen attached to it) through various pathways and attempted to stay within the pathway 75% of the time. The goal score was scaled according to the complexity of the shape of the pathway:

-2 (initial status) =	straight line
-1 (somewhat below expected) =	zigzag
0 (expected status) =	curvy
+1 (somewhat above expected) =	loop
+2 (much above expected) =	sophisticated shaped board game (i.e snakes and ladders)

For the communicative goal, the participant was to use her SGD during robot activities to produce two to four word utterances. The goal score was scaled according to the level of support required:

-2 (initial status) =	copying samples
-1 (somewhat below expected) =	using a list of suggestions
0 (expected status) =	reviewing a list prior to activity and receiving verbal cues to help generate them
+1 (somewhat above expected) =	reviewing a list prior to activity, but independently generating them
+2 (much above expected) =	independently generating them

Hypothesis
After learning to use the robot via her SGD, the participant will achieve increased operational and communicative goal scores.

Materials:
AAC Device
The SGD used was the Vanguard[2] II, with Unity[3] 45 Full vocabulary set, Version 4.06 Nov 29, 2006. Two Jelly Bean[4] switches were attached with Velcro[5] hook and loop fasteners to the wheelchair headrest. The Language Activity Monitor[6] (LAM) was used to log language and IR commands during the sessions.
Robots
Two robots were built from the Lego Mindstorms[7] kit: a car-like roverbot and a robot arm (Figure 1). The robots were controlled by direct commands to individual motors (forward, backward, and stop), or by a program of a sequence of movements (e.g., turn in a circle and go forward for 8 seconds). A Lego remote control unit was used to train the IR signals into the SGD. The participant had the ability to press and hold her switches, and she often used this strategy in controlling the robots. The SGD's auto repeat was set to 0.7s.

Intervention
After one demonstration session, the participant received training and used the robot for functional activities for 12 sessions over 14 weeks. The intervention protocol progressed using an increasing number of functions and complexity of tasks. The types of activities that the participant performed are shown in Table 1.

Communication was encouraged during all activities. For instance, players used appropriate comments during board games (i.e. "your turn") and one game required two word answers. The participant directed investigators to do the puzzle making tasks that she could not perform with the robot, and she generated the script for a character in the Greek myth.

A new page was created for the robot commands, which included some vocabulary (i.e. "It's not working", "This is fun", "This is boring"). Investigators prompted the participant to use vocabulary already present on the device, as well as programmed additional vocabulary as necessary (i.e. "smart move").

RESULTS
Operational Goal: Accuracy was determined by taking a ratio of the distance traveled within the pathway over the total distance traveled. The freeware program ImageJ[8] was used to make the measurements from photographs of the pathways. Accuracies for the different pathways are shown in Table 1. The participant's accuracy was better than 75%, but a more sophisticated shaped board game was not attempted within the 12 sessions, thus the final GAS score for this goal is +1.

Communicative Goal: The LAM logfiles were analyzed according to rules for counting mean length of utterance (MLU) adapted from Van Tatenhove (2006), who recommended a 90 second interval for scanning users:

- repeated words within 90 seconds with no IR commands sent in between were counted as one, and repeated words with IR commands sent in between were counted individually
- pre-stored sentences counted as single utterances
- pre-stored phrases representing a grammatical phrase (e.g., I want, I like) were counted by morphemes, while pre-stored ending phrases that followed (e.g., go swimming) were counted as one morpheme only.

MLU was tracked during robot tasks and during “chatting” time for 11 sessions (forgotten once). As seen in Table 1, the participant’s MLU ranged from 1 to 1.9 during tasks, and 1 to 2.5 during chatting. A final GAS score was not determined since supports were not provided as suggested in the goals.

DISCUSSION

The participant achieved an increased operational goal score by demonstrating the required accuracy. The goal did not specify how efficient the participant should be, and initial calculations show that she traveled 1.2 to 3.2 times longer than the most direct path. Future accuracy measurements should have an optimal path to follow, and measure the root mean square distance from it.

As the communicative goal for the participant was to use two to four word utterances independently, we had hoped to see an upward trend in MLU. However, the participant's MLU remained relatively consistent over time, likely due to many factors. First, the participant was not given many opportunities or the necessary supports for verbal output, largely due to implementation challenges for the investigators. Second, the participant made a tradeoff between operating the robot and communicating. She was very interested in playing, and though she frequently used the pre-stored phrases on the robot page (which counted as one morpheme each), she did not use the core vocabulary on her device unless prompted. She did spontaneously use directed eye gaze and other non-verbal cues. Third, since some selection sequences were quite long and two-switch scanning was inefficient, shortcuts were created, and this could have reduced the calculated MLU. It was difficult to determine the nature of an utterance (e.g., initiation, comment, request) since logfiling only documents one side of the interaction. Videos of the sessions will be reviewed to determine communicative function as well as to analyze non-verbal communication (Higginbotham & Cornish, 2002).

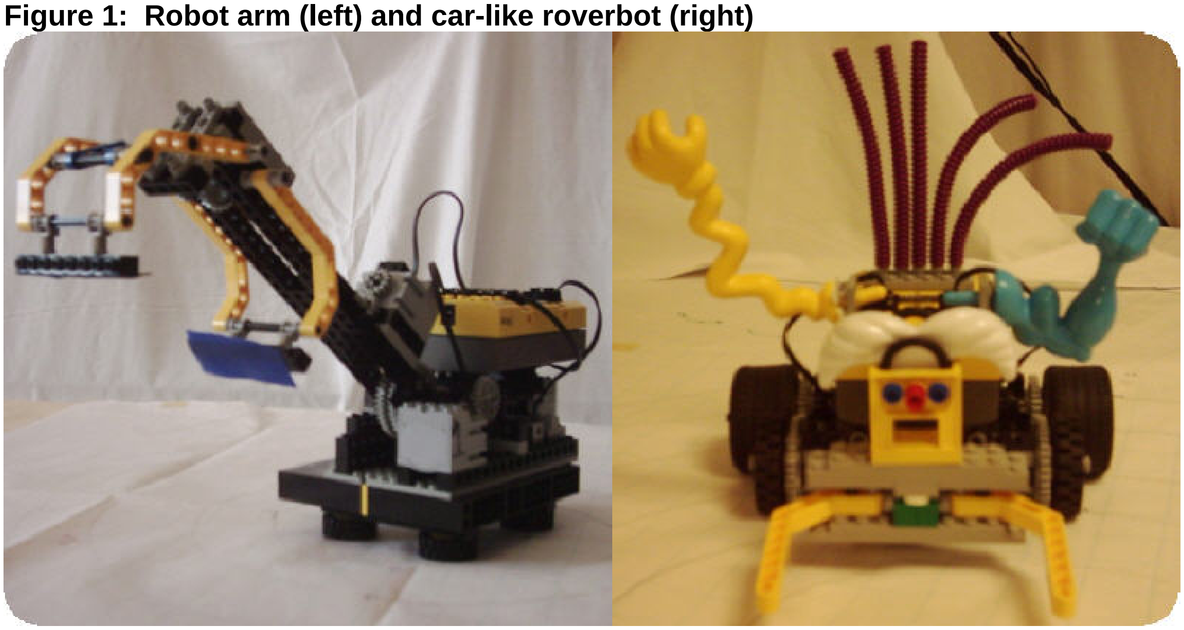
The teacher was very happy with the participant's progress and said the participant "found it very motivating and fun", "it afforded her opportunities to use her thinking skills" and "the work she has done with the robot has helped to improve her skills with the communication device in day to day communication."

Overall, the feasibility of controlling Lego robots through a SGD was demonstrated with an increased operational goal score and although the communicative goal score did not increase, valuable information was obtained regarding intervention protocol and goal setting for future studies.

Table 1: Robot Activities and Operational and Communicative Measures

Activity	Accuracy in Pathway Activities	# Task related Words	Length of utterance	# Chat related Words	Length of utterance
Draw flower using circles and lines		7	1		
Follow **straight** pathway as game with words	Not measured	36	1.2		
Follow **square** pathway	68% Trial 1 88% Trial 2	24	1.2		
Follow **long zig zag** pathway as game, roll dice with robot arm via switch	88% Trial 1 96% Trial 2	22	1.1	30	2.5
Follow **short zig zag** pathway as game, roll dice with robot arm via switch Follow a **maze** Connect dot to dot of a bat	90% 99%	11	1.1	7	2.3
Follow **loop** pathway as game, roll dice with robot arm via SGD	90% Trial 1 93% Trial 2	28	1.2	26	2.2
Orient and place puzzle pieces, square shape		23	1		
Orient and place puzzle pieces, rectangular shape		24	1	10	2
Connect dot to dot of a spider web		17	1.5		
Acting the parts in a Greek myth, Part 1		21	1.5		
Acting the parts in a Greek myth, Part 2		39	1.9	14	1

Figure 1: Robot arm (left) and car-like roverbot (right)



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