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# INVOLVING USERS IN THE DESIGN OF A SPEECH GENERATING DEVICE INTERFACE FOR LEGO ROBOT CONTROL

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## ABSTRACT

This paper describes the process of developing a speech generating device (SGD) interface to control Lego robots which involved the end-users in testing and iterative improvements of the interface. The participants had differing skills and preferences which resulted in individual interfaces which varied in navigation system, symbol type and organization. The resulting interfaces were functional for the participants as evidenced by their performance in robot control training and functional math activities.

## INTRODUCTION

In this study, three participants used their own speech generating device (SGD) and alternative access method to control a Lego(TM) robot to perform math activities. Using their own device addressed a limitation in other assistive robot studies where children who had severe physical disabilities had difficulty using the robot controllers (1, 2). With the SGD and robot they had an integrated system for doing manipulation with the Lego robot and talking with their communication device. In an integrated SGD and robot pilot study a participant performed various school activities using an SGD page containing robot commands and some communicative phrases (3). She was functional at controlling the robots, but she did not change modes between communication and robot control often. As a result, the investigators recommended that the robot commands be present alongside the core vocabulary instead of on a separate page.

To increase the usability of devices, human factors engineers (4) and AAC users (5) encourage the involvement of end users and other stakeholders in all stages of device development: i.e., 1) requirements gathering, 2) iterative development of device concepts, and 3) testing the usability of devices. Although there are examples of involving adults with disabilities and children without disabilities in these design stages (6-9), involving children with disabilities is not well studied.

This paper describes a process of developing an SGD interface to control Lego robots which involved the end-users in testing and in iterative improvements of the interface.

## METHODS

<u>Participants</u>

Three children who were diagnosed

with spastic athetoid quadriparetic cerebral palsy participated in the study. M01, was a 14 year old female, M02 was a 10 year old male, and M03 was a 12 year old female. They used their own Vanguard(TM) II SGDs which they activated using two Spec(TM) switches, located at either side of their wheelchair headrests. They all used step scanning, where M01 and M02 used row-column scanning and M03 used group-row-column scanning. M01 and M02 used the Unity(TM) 45 Full Language system and M03 used Unity 84 Sequenced.

Materials

The integrated communication and robot control system was operationalized by using the participant's own SGD and a car-like robot, built from the Lego Mindstorms for Schools Kit (TM). The robot could be controlled using programs or the robot motors could be controlled directly. The robot also had a gripper mechanism which could open and close. The gripper could be replaced with a mechanism for moving a pen up and down, depending on the requirements of the task. Colored arms from the Mr. Potato Head(TM) game were added to the robot to facilitate deciding how to turn left (toward the yellow arm) and right (toward the blue arm). It was expected that the color coding would help when the robot was coming towards the user, where mental manipulation is required to determine which direction is which with respect to the robot. A Lego infrared (IR) remote control unit was used to train the SGD to send the required IR signals to the robot.

Procedure

Initial SGD characteristics were documented and then tracked during robot control training sessions and in math sessions. The participant's initial SGD grid size, language system, and scan type was used for the duration of the study with the exception of M03 who changed to a grid size of 84 during the math sessions (for reasons not related to this study). The SGD auto repeat feature was set to 0.7 for all participants. This allowed them to press and hold a selection (e.g., forward movement) to obtain continuous robot movement for long distances.

The robot commands required for the training sessions were commands to directly control the robot motors for:

- forward and backward movements (individual movements were approximately 10 cm. in length) and left and right (optionally color coded yellow and blue to correspond to the robot arms)
- gripper open and close
- (optional) pen up and down (these were optional since the gripper open and close commands could be used instead)
- (optional) small forward, backward, left and right movements (approximately 2 cm. in length)

During the math sessions the following program commands were added:

- programs to move the robot forward by one unit length (e.g., one toothpick, rod, or straw)
- programs to move the robot forward by one giant step and one baby step

An initial interface design was suggested to the participants based on the findings in the pilot study. The layout consisted of an activity row (a row of symbols which remain on the top row with the core vocabulary below) with robot commands in frequency order of use (forward, left, right, backward, stop, and programs). The SGD navigation system (e.g., having robot commands on an activity row or on a separate page), symbols for mapping to robot movements and their organization (location) were negotiated with each participant and modified during robot training sessions according to the participant's skills and preferences in order to obtain better system usability. Modifications were made to obtain better accuracy and time on the robot control training tasks and to reduce participant effort.

## RESULTS

Figure 1 shows each participant's interface at the start of the study, after robot training and after the math sessions. Only M01 used the robot commands on the activity row for the duration of the study. She stated that she preferred it over a page of commands because it was "easier". The order of her commands changed because she had a tendency to accidentally hit the first item in the scan row. The investigator initially suggested leaving the original "." in the first position because it was benign, but the participant insisted that forward be placed there. She continued to accidentally hit that cell in the training and math sessions, causing the robot to move forward, thus reducing accuracy. However, she usually corrected the robot position by sending the backwards command. M02 immediately rejected the idea of using an activity row and created his own SGD page, assigned commands to cells, and labeled them with words. His habit was to put the symbol to change to the core vocabulary in the first position. He initially entered the remaining commands in the order in which they were described to him (from the list above), but after he was told that he could rearrange the commands so that the more frequent commands were closer to the first scan position, he independently rearranged the symbols into his perceived order of frequency.

M03 used the suggested activity row for part of the training, but soon decided to use a

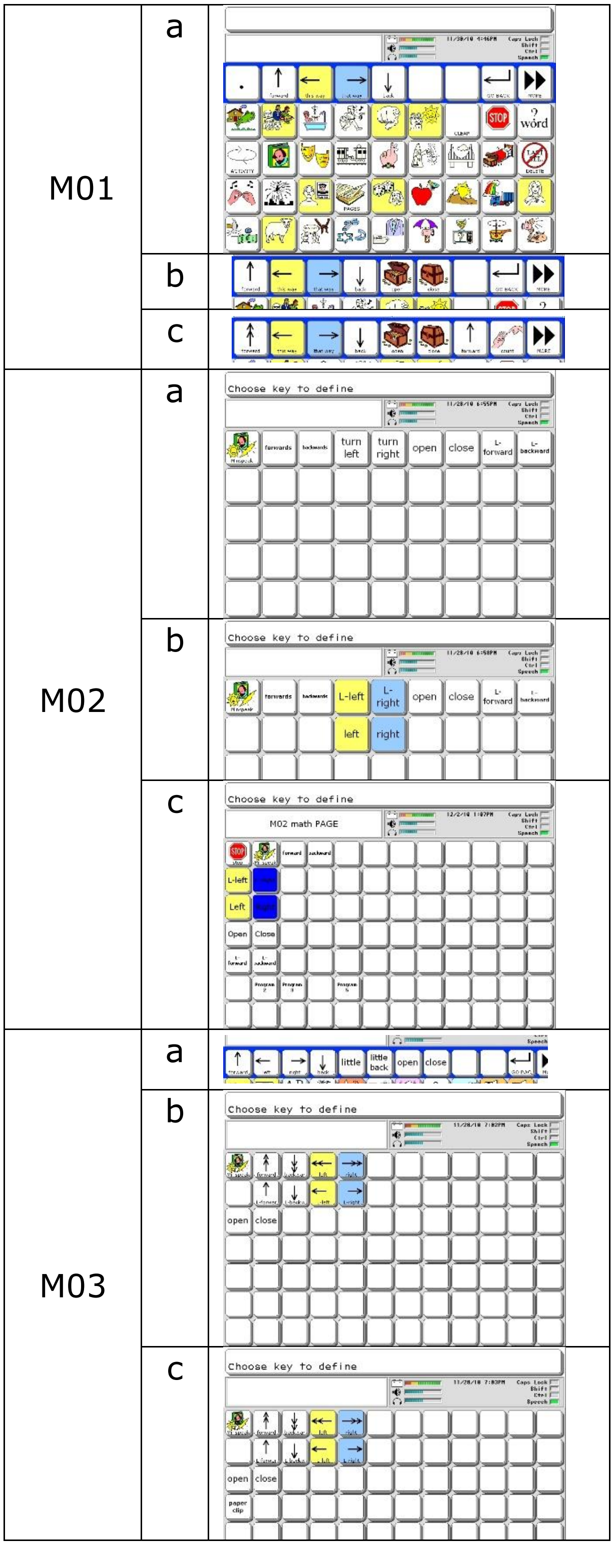


**Figure 1:** SGD interfaces: (a) initially, (b) after training, and (c) after the math sessions. Screen captures created using PASS(TM) software.

page instead. The page was not quite in frequency order, because the forward and backward commands were placed together. The regular-sized robot movements were in one scan group and all other commands were in another group.

All participants decided to use the optional color coding for left and right turns of the robot. They also decided to use the same cells for pen up/down as gripper open/close. However, this caused problems for M01 and M03 since they frequently hit the opposite command than required. It did not cause accuracy problems in the training or math activities unless the participant made the pen go down so many times that the robot rose off of its wheels and set down in a different position. If so, the robot was placed back in its original position. In spite of those problems, they still did not elect to have separate buttons for the gripper and pen.

M02 and M03 elected to have the small movement commands added to their interfaces early on during the training activities. M01 was not interested in having the commands but the investigators insisted that a small forward command be added for the math sessions so that she could attain the required accuracy in the functional tasks. When the small movement commands were added, the symbols for the regular movements were modified to those depicting large cursor movements on the Mouse commands page (segmented arrows).

Instead of using the "more" cell to access more symbols to send program commands, M01 preferred to access them by linking to a page (the 8th cell in her activity row). M02's SGD required a

Lego IR STOP command to be added at the end of each program command in his SGD in order to send sequential program commands. Even though the SGD was programmed to send both the program and stop command when the cell was selected, a STOP command was also added to his interface. On his own, he discovered the strategy to run the Giant Step program and then press STOP at the target location and he preferred to use this strategy instead of the press and hold strategy suggested by the investigators. M02 independently moved the stop button to the top left location so he could quickly select it.

## DISCUSSION AND CONCLUSION

Using their own SGD gave the participants the benefit of using the language system and access method with which they were already familiar to control the Lego robot and have an integrated system to do and talk about math. This approach addressed the limitation in previous robot studies where it was difficult to find an appropriate access method for children with severe physical limitations to control robots. The participants had differing skills and preferences which resulted in interfaces which varied in navigation system, symbol type and organization. For instance, having the robot commands available alongside the core vocabulary was preferable for M01, whereas M02 and M03 preferred to use a separate page for robot commands. They all easily switched between "doing" and "talking" modes, but pages may have been easier for M02 and M03 since they had more experience using their SGDs than M01.

One disadvantage of using the activity row was the large number of switch hits required to access commands far from the initial scan position. This was probably a factor in M01's reluctance to use the small forward command which was located 7 positions from the scanning start position. The high number of switch hits required to make selections is probably also a factor in why participants preferred to use the gripper open/close commands for pen up/down in spite of the confusion it caused them. Adding separate commands for pen up/down would require more switch hits to access all of the commands.

M02 and M03 used words instead of symbols since they had good reading skills. The color coding for left and right turns was desirable by all three participants. The symbols for the large and small movements seem counter intuitive (large cursor movements were depicted with small segmented arrows) but they were used since the participants had previous experience using the Mouse commands page.

The organization of the symbols affected accuracy, but was influenced by participant preference. M01 insisted that the forward movement be placed first in spite of the accidental hits and time required to fix the error. M02's preferred strategy for going long distances resulted in an interesting interface where the first symbol caused no robot movement or SGD page changes if it was selected unintentionally. The STOP command, which had the highest timing demand, was in the first position where M02 could select it quickly.

The resulting interfaces were functional for each of the participants, as evidenced by their performance in the training and math activities (10).


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