

Learning Switch Scanning Skills by Playing with Robots

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Abstract. Manipulating and controlling assistive technology (AT) tools remains challenging for some children with severe multiple disabilities. In the area of communication, for example, augmentative and alternative communication (AAC) via switch scanning may be an optimally viable option for children with significant physical limitations. However, children's acquisition of switch scanning may be hampered by the dearth of evidence-based training protocols and the cognitively demanding nature of the task, diminishing motivation. Introducing AAC scanning skills may be facilitated by incorporating switch-controlled robots. Robot mediated play tasks can be designed such that specific switch scanning skills are trained in a potentially engaging setup. This paper reports the technical developments of physical and software-driven virtual robots controlled using switches to perform different play activities. A robot mediated switch training protocol informed by end-user trials is also reported.

Keywords. Robot, augmentative communication, computer access, scanning

Introduction

Persons with significant impairments in speech and writing use assistive technology (AT) like augmentative and alternative communication (AAC) devices for verbal communication and/or alternative computer access methods for written communication. Limited physical ability to manipulate and control AT tools remains challenging for children with severe multiple disabilities. For some, single switch control may be the only viable method for accessing AT. To access more than one choice with one switch necessitates using scanning. Instead of directly pointing out a single item amongst an array of choices, a person using scanning uses one or two switches while watching a screen display of all possible choices. For example, in two-switch step-scanning, the person scanning repeatedly presses a switch to make a visual marker highlight each choice, first down each row and uses the second switch to select their target row. Then the person repeatedly presses the first switch to make the visual marker highlight each cell in the row and presses the second switch to select their target cell. Scanning is a cognitively demanding task, involving cause-effect, sequencing, attention, anticipation, and memory skills, which some children have difficulty learning [1]. A review of the literature reveals a lack of evidence-based practice surrounding teaching techniques for switch scanning, and an employment of methodologies primarily based on clinicians' choice [2]. In one study comparing methods to teach scanning to children with cerebral palsy (CP), four children used a paper-based scan method (a partner moved a red cardboard window to highlight the choices on a paper grid) and four children used a computer-based method [3]. Though no children showed improvements from baseline to intervention, the children in the paper-based method experienced learning of skills, but it was not captured in the outcome measure (a computer-based scanning test). The paper-based protocol included play between trials, which investigators felt was beneficial to the children, encouraging choice making and matching with their interests.

Robot control can be done through the use of switches and requires the same basic skills as for switch scanning. In a protocol we have trialed in multiple studies children used cause and effect, inhibition, laterality and sequencing to control the robots in playful activities [4, 5]. Children operated, with one to three switches, both physical and virtual robots in real and virtual environments, respectively. Multiple, individualized scenarios (e.g., knocking over blocks, a prince bringing a rose to a princess, or a farmer bringing hay to some animals) were designed to maintain children's interest [6].

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Robots, if designed correctly, are appealing to children [7] and activities requiring different robot control skills, and thus different switch skills, can be devised to keep children motivated. In this way, learning switch skills can be decoupled from the utilization of a computer or AAC device and can be done in a play environment, potentially more engaging to children. Virtual robots can simulate scanning on a computer display and potentially help to bridge the gap between controlling a physical robot and accessing AT. This paper presents the development of a training protocol for learning and practicing scanning switch skills while controlling a physical and virtual robot. It is recommended to involve end users and other stakeholders, including children [8] in iterative design development of technology and interventions [9, 10]. Thus, our protocol was informed by observing children in the training activities.

1. Methods

A training protocol for learning 2-switch step-row-column scanning was proposed. It included practice activities (to generalize previous switch activity learning to the protocol activities) and various activities using the physical robot and then a virtual robot in a scanning grid array (e.g., cooperative activities where the participant moved the robot to a grid cell and then an assistant picked up the item and put it on the robot).

1.1. Materials

Various existing materials were used, including: two Jelly Bean[®] switches, mounting arms to position the switches, switch-activated toys, a voice output communication device (VOCA), and various game pieces (e.g., Mr. Potato Head[®], zoo animals, and small wooden blocks).

1.2. Technical Development

The robot control programs developed for doing the tasks described above [4,5] were adapted to be used such that the robot moved like a visual marker on a scanning grid. Microsoft[®] Robotics Developer Studio 2008 R3 (MS-RDS), a freely available programming environment, was used to control both the physical (via a Bluetooth remote link) and the virtual robot from a laptop computer. Applications may be created using a Visual Programming Language or C#. The technical details of the robot control programs are presented in [6].

For the physical robot and physical environment, a Lego Mindstorms[®] NXT 2.0 Tri Bot was placed on a mat (size = 69x69 cm) representing a three row by three column (3x3) scanning grid (Figure 1, left). The mat could also be folded to be 1x3 or 3x1. Items could be placed on the mat, or symbols representing items could be inserted into the plastic sleeves of the mat.

For the virtual robot and virtual environment the MS-RDS simulation environment was used. It includes models for a variety of robots, including the NXT Tri Bot. A virtual environment simulating the real-world physics of the robot movement and the texture of the mat was developed within MS-RDS. Any JPG picture can be imported as a mat into the virtual environment. Hence, a photograph of the physical mat, a hand drawing or a grid created with a program such as BoardMaker[®] could be used. The grid can be any row x column dimension (Figure 1, right).

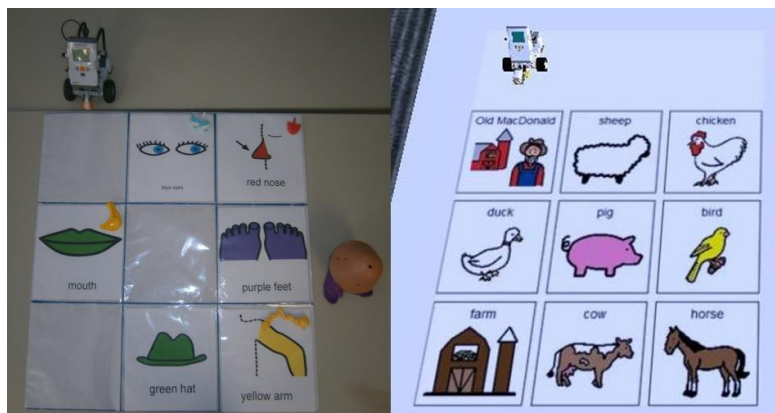


Figure 1. Physical robot and environment (left) and virtual robot and environment (right)

The Graphical User Interface (GUI) service was used to create a console to perform the following functions:

- Set the distance that both the physical and virtual robots move forward in each forward step movement, thus providing a means to adapt to the grid dimension.
- Position the virtual robot to the top left corner of the mat (as in scanning).
- Choose the scanning method:
 - o In step mode, the switches behaved as follows: Switch 1 moved the robot down one row with each press (move), then Switch 2 turned the robot towards the row (select), then Switch 1 moved the robot across one cell with each press (move) and Switch 2 spun robot in a circle (select).
 - o Inverse, automatic, and directed scanning [11] were implemented, but not tested.

Within MS-RDS, the up arrow and left arrow on the key board were used for "switch hits" (the function of each depended on the scanning method). Two standard Jelly Bean® switches were connected to the computer via a Switch Interface Pro 6.0ⁱ configured such that the two switches emulated the up and left arrows.

1.3. Participants

Two children with CP participated in the trials. Participant 1 was a 7-year-old girl with dystonic quadriplegia. Participant 2 was a 6-year-old boy with spastic quadriplegia. No formal cognitive assessment was performed. By report they likely had a developmental delay, but the severity could not be specified. They were both non-verbal, and were reported to have previously activated VOCAs and switch adapted toys using switches mounted beside both sides of their head.

1.4. Trials

After obtaining ethics approval, the participants underwent trials of the protocol. Different activities were proposed to each participant in order to evaluate the robotic system and to inform the design of a suitable switch training protocol. We observed if the participants had success or not on trials and the amount of prompting needed, and adapted the protocol as needed.

2. Results

The resulting protocol is shown in Table 1. Participant 1 performed the practice switch activities (Steps 1 and 2 in Table 1) and then used the physical robot in the grid set up (Steps 8 and 9). She did not control her second switch reliably (tending to lay against it), so adaptations were made to accommodate her abilities. Instead of controlling the robot with the switch she used a VOCA to say "that's the one I want" and eye blinks to confirm her selection. In one trial, a 1 row x 3 column grid was displayed on a wall with beads taped to the grid. The physical robot travelled from left to right on a table in front of the grid with a "selection window" placed on top of it (so she could see what bead she would select). This is like the paper-based scanning training method in [3], and was added to the protocol (Step 8b).

Because Participant 1 had trouble inhibiting pressing Switch 2, the robot tasks from [4, 5] were added to the protocol to establish if children understood cause and effect, inhibition, laterality, and sequencing skills with the robot (Steps 3-6 in Table 1). After trialing with Participant 2, the original tasks were modified slightly. In [4, 5] the robot travelled away from the child, but in this study it was placed so that it travelled towards the child (like a visual marker scanning down the rows). In [4, 5] Switch 1 moved the robot forward as long as the switch was pressed, whereas in this study Switch 1 moved the robot forward a distance of 10 cm, thus requiring multiple "steps" of the robot. Also, in [4, 5] Switches 2 and 3 were used to turn by 90 degrees the robot to the left or right, respectively. In this study, one switch was used to turn the robot to its left (i.e., the child's right), thus subsequent forward presses made the robot travel from left to right like the visual marker scanning across cells in a row.

Finally, both participants seemed to enjoy making the robot turn and spin (more than trying to achieve the target task at times). Therefore free play with the robot to allow the children to become familiar with the robot and switches before asking them to concentrate on the tasks was included in the protocol, too (Steps 7 and 10). Also, an assessment to ensure easy, reliable switch activation sites should be performed prior to the protocol.

Table 1. Training protocol for 2-switch step-row-column scanning with robots. NA = Not applicable

Task	Step #	Skills needed	# Switches	Grid size (row x column)	Example activities
Practice pre-existing switch skills, based on [12]	1	Cause and effect	1	NA	Activate a VOCA to play a prerecorded phrase (e.g., "more bubbles")
	2	Cause and effect -two functions	2	NA	Activate Switch 1 to make an adapted toy walk and Switch 2 to play a prerecorded phrase "Yeah, I made it!"
Robot skills based on previous protocol [4, 5]	3	Cause and effect	1	NA	With robot travelling towards child, press and release switch 1 repeatedly until robot knocks over a stack of blocks.
	4	Inhibition	1	NA	Press and release Switch 1 and stop when robot next to a stack of blocks. Helper puts a block on top of robot. Press and release Switch 1 until reach location to unload block.
	5	Laterality	2	NA	Press Switch 2 to turn the robot towards a stack of blocks placed to the right of robot.
	6	Sequencing	2	NA	After turning, press and release Switch 1 until robot knocks over the blocks.
Physical robot with grid set up (For layout see Figure 1, left)	7	All previous	2	None	Free play: The child explores what happens when he presses the switches.
	8 a	All previous	2	3 x 1	With robot travelling towards child one row at a time, press and release Switch 1 until the third row of the grid where there is a pile of blocks. Press and release Switch 2 to select it and the robot spins, knocking over the blocks.
	8 b	All previous	1	1 x 3 taped to wall	Each cell has taped to it a different bead for a bracelet. With robot travelling from left to right one cell at a time, press and release Switch 1 to move the robot to the desired cell. Press and release Switch 2 to select the cell and the robot spins to indicate selection.
	8 c	All previous	2	1 x 3	Same as 8a, but with robot travelling from left to right one cell at a time.
	9	All previous	2	3 x 3	Some cells of the grid contain Mr. Potato Head parts or symbols (e.g. eyes). The robot faces the child in the upper-left corner of the grid. Switch 1 moves the robot down the row and Switch 2 selects (the first select turns the robot 90 degrees, reorienting it along the desired row, and the second select spins the robot to signal desired cell. The Mr. Potato Head's part in that cell is added to his body.
Virtual robot with grid set up (Figure 1, right)	1	All previous	2	None	Free play: The same as 7.
	1	All previous	2	1 x 3	The same as 8c.
	1	All previous	2	3 x 3	The same as 9.
	2				
Communication Device	1	All previous	2	3x3 and higher	E.g., Exploration Wizard Targets, Chase the Rabbit ⁱⁱ
	3				

3. Discussion and Conclusion

Through the technique of scanning, the ability for children with disabilities to use communication devices and computers for writing for participation in school and leisure activities can become a reality. The robot training protocol can be a potentially motivating and effective training method to help achieve this goal. We developed the software and hardware to support robot mediated play activities to be included in a training protocol to support scanning skills for children with motor impairments. Trials with two children with severe motor impairments informed a protocol to progress from previous switch experience to using physical and virtual robots in grid arrays.

Future research will involve trialing the protocol with children with disabilities for more sessions to build skills to use the virtual robot scanning grid, and finally other AT such as a communication device.

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ⁱ Don Johnston, Inc. <http://www.donjohnston.com>

ⁱⁱ <http://www.prentrom.com/training/courses/devices-m1/where-do-i-begin/exploration-wizard-targets>