VIRTUAL ASSISTIVE ROBOTS FOR PLAY, LEARNING, AND COGNITIVE DEVELOPMENT

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Abstract

Previous studies have demonstrated that Lego robots can be used to enable children with motor impairments to actively participate in play and academic activities. Additionally, by appropriately designing the activities and observing children's performance, it is possible to assess children's cognitive skills. In this work we developed physical and virtual robot scenarios as a first step towards the evaluation if the same benefits for children could be obtained using virtual robots in a simulated environment. Our study with ten adult participants without disabilities showed that the virtual robot was easier to control than the physical one.

Introduction

Children who have movement disorders such as cerebral palsy may have difficulty in manipulating objects, and this can compromise the quality of play and learning of skills [1]. Consequently these children may be perceived as being more developmentally delayed than they actually are, leading to reduced expectations on the part of teachers, clinicians and parents. Using robots controlled by the children provides an opportunity to manipulate real objects and engage in play activities, thus increasing the opportunities to learn cognitive, social, motor and linguistic skills [2].

Poletz, Encarnação, Adams, and Cook [3] evaluated the ages when typically developing children demonstrate basic skills necessary to control robots and other assistive technology, such as scanning access methods to augmentative and alternative communication devices. Eighteen children in the age ranges 3 years ± 3 months, 4 years ± 3 months and 5 years ± 3 months participated in the study. They controlled the Lego(TM) Mindstorms RCX 2.0 robot using 3 switches and a switch adapted infrared controller. The children were observed performing different play activities with the robot from which it was possible to see if they demonstrated cause and effect, negation, binary choice, and sequencing skills. The study showed that children demonstrate skills according to their age level. These robot skills may be used as a proxy measure of cognitive skills for children who are "untestable" with standardized tests. However, cost and hardware availability may be limitations for widespread use of the robots so the purpose of this study was to investigate the feasibility of using a virtual assistive robot. The objective was to develop simulated and real scenarios in which children could control the virtual and physical robots using switches and then test whether the virtual robot provided the same control experience compared to the physical one. If the answer is yes, then future studies should investigate if a virtual robot has the same performance in helping children with

disabilities to play, learn, and develop their cognitive ability as in previous studies.

Physical and Simulated scenario DESIGN

The scenarios in the original study consisted of four tasks [3]:

- Task 1, Causality: Children were expected to press and hold the switch to drive the robot until it hits the blocks at the end of the path (see Fig 1, left).
- Task 2, Negation: Children were required to stop midway down the path (i.e., releasing is an action) so blocks could be loaded on to the robot, and then they had to stop at the end so the blocks could be unloaded (see Fig 1, middle).
- Task 3a, Binary Logic: The robot was placed between two stacks of blocks. Children were asked which stack they wanted to knock over, and then were expected to turn the robot in the appropriate direction using the two new switches. The robot turned left or right by 90 degrees with a press and release switch hit (see Fig. 1, right).
- Task 3b, Sequencing: After turning, children were expected to subsequently press the switch for forward movement until the robot hit the blocks.

Figure 1: Physical robot environment: (a) is the environment for Causality, (b) is for Negation and (c) is for Binary Logic and Sequencing

Robot control

A set of three switches was used to control the physical and the virtual robots. These switches were connected to a computer via a switch interface device (Intelliswitch, from Madentec) and mapped to the functions of the arrow keys on the computer keyboard. The robot control programs for the tasks were developed using Microsoft Robotics Developer Studio (MS-RDS), a Visual Programming Language in a Windows-based environment [4]. The switch actions were programmed to be as follows, using the "Differential Driver" MS-RDS service:

☐ "Up switch" (move straight forward): when the "up switch" was pressed, the robot moved forward. It stopped when the switch was released. Thus, to make the robot continuously move forward, the user needed to press and hold the switch.

☐ "Left or right switch" (turn 90 degrees): when the "Left or Right switch" was pressed, the robot turned accordingly by exactly 90 degrees. The children did not need to hold these switches down to make the robot turn.

Physical Robot

A Lego NXT Mindstorms robot was used for the physical robot. MS-RDS provides a service called Lego NXT brick to control this robot. After the robot is connected to the computer via bluetooth, this service can be used to send commands to the robot

according to the user switch actions.

Virtual Robot and Simulation Environment

The simulated scenario was designed using DSS Manifest Editor and run using Microsoft Visual Simulation Environment, which enables real-world physics simulation for robot and environment models (both software are included in MS-RDS). The entities needed for the above mentioned scenarios were:

☐ Lego NXT Robot: Available in the sample set provided by DSS Manifest Editor.

☐ Blocks: The "SingleShape" entity class provided by DSS Manifest Editor was used. This "SingleShape" class allows creation of an object with certain shapes, such as a box, sphere, capsule and so on. In the scenarios in this project the box shape was used in several ways:

- Cube blocks: items to be knocked down.

- Sheet: In the previous study, an orange sheet marked with the robot and blocks positions was used to facilitate replication of the experimental set up. The height of box shape was adjusted to be flat like a sheet, and colored orange. The friction parameters were set to be similar to the physical world (dynamic and static friction of 0.5 and restitution parameter of 0.2).

- White marks: White marks along the path were used to measure how close to given points the children managed to stop the robot. They were set to be thin enough not to disrupt robot movement (0.003 in).

The three simulation worlds designed corresponding to Tasks 1, 2 and 3 are shown in Figure 2. The position and object size were set according to the ratio of the physical world objects.

Loading and unloading the blocks in Task 2 (negation) was not implemented in the simulation environment. Instead, speech feedback through the "Text to speech" service was used to indicate children successfully stopped at the correct location.
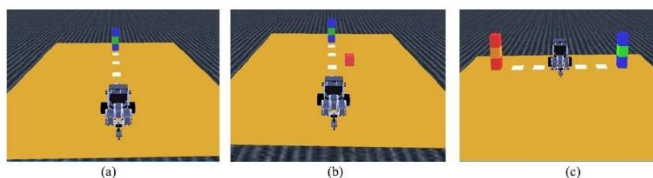

Figure 2: Designed simulation environment: (a) is the environment for Causality, (b) is for Negation and (c) is for Binary Logic and Sequencing

User Study

Ten adult participants without disabilities, four females and six males, participated in the user trials. A new simulation environment and a different task were created to have a more complicated task for the adult users to complete. The simulation environment used in this experiment is shown in Figure 3. The physical scenario matched the virtual one. The participants were required to drive the robot to the first white mark, then turn left and forward to the next mark, then turn left and proceed to knock down both sets of blocks. This protocol encompasses all robot maneuvers required to perform Tasks 1 to 3 above.
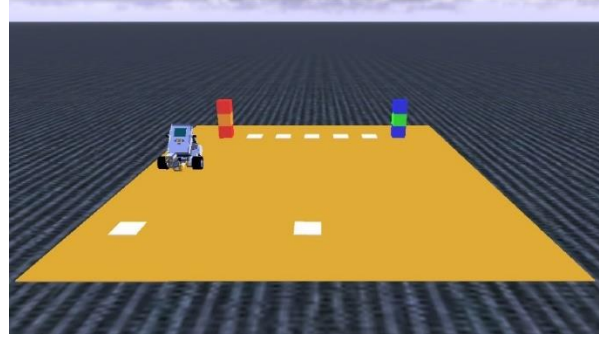
Figure 3: Simulation environment used in the user study

All participants did the task with both the physical and virtual robots. Five of the participants were randomly selected to begin with driving the physical robot (Group A) and the other five started with the virtual robot (Group B). They were given some warm-up time to get familiar with the switch controls. The time to complete the task was recorded by an observer with a stop watch.

T-tests (p-value < 0.05) were performed to see whether the mean time to complete the task with the virtual robot was less than the mean time to complete the task with the physical robot.

Five subjective evaluation questions regarding robot control and scenario perception were administered (shown in Table 3). Participants rated if they strongly disagreed to strongly agreed on a five point scale.

Results

Table 1: Time to complete the task with the physical and virtual robots.

	Group A - physical robot first (seconds)					Group B - virtual robot first (seconds)				
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Virtual Robot	50	31	40	58	18	83	45	32	51	49
Physical Robot	97	69	84	70	45	58	62	43	119	43

Table 2: Mean value of the time to complete the task with the physical and virtual robots

	GroupA (seconds)	*Group B (seconds)*	*All Participants (seconds)*
Virtual Robot	39.4	51.4	45.4
Physical Robot	73.0	65.0	69.0

T-tests assuming a Normal distribution of the times were calculated for the means for all three cases: Group A, Group B and the combined groups. The p-value was 0.00313 for Group A, 0.2166 for Group B, and 0.01151 for the combined groups. Thus, for participants in Group A, the mean time to complete the task using the virtual robot was significantly lower than the mean time to complete the task using the physical robot. That was not the case for the participants in Group B. Combining the data from

all participants, again one can conclude that the virtual robot was significantly faster to complete the task than the physical one.

The subjective evaluation ratings from all of the participants are summarized in Table 3.

Table 3: Answers to the subjective questions. SD=Strongly Disagree, D=Disagree, N=Neutral, A=Agree, SA=Strongly

SD	D	N	A	SA
Question 1: Do you agree that the physical robot is easier to control the [perceived] speed than the virtual one?				
5	2	2	1	0
Question 2: Do you agree that the physical robot is easier to turn 90 degrees than the virtual one?				
5	4	0	1	0
Question 3: Do you agree that the camera view of the virtual robot makes it more difficult to drive the robot?				
2	3	0	5	0
Question 4: Do you agree that the objects in the simulation are unrealistic?				
1	4	3	2	0
Question 5: Do you agree that the moving and colliding effects in the simulation are the same as in the physical world?				
1	5	0	3	1

Discussion and Conclusion

In this project, we designed a virtual assistive robot using Microsoft Robotics Developer Studio. After having implemented causation, negation, binary, and sequencing task scenarios in both a virtual and physical assistive robot environment, we conducted an evaluation with 10 adult participants without disabilities. The evaluation was based on a timed task which included all of the aforementioned tasks and a subjective evaluation. The time for participants to complete the task with the virtual robot was significantly faster than the time to complete the task with the physical robot. Looking at individual data, eight participants performed the task faster with the virtual robot. The two participants who were slower with the virtual robot used it first, so they may have had some problems getting used to the switch controls.

Most participants chose Disagree or Strongly Disagree in Question 1. The speed of the physical and virtual robots was set to be the same, but the acceleration of the physical robot seemed to cause problems for participants, and no parameters in MS-RDS were found to adjust it. Most participants also chose Disagree or Strongly Disagree for Question 2. However, this result is influenced by a hardware issue where the physical robot did not always turn exactly 90 degrees due to the position of the back wheel. Question 3 and Question 5 which concern the camera view and colliding effects in the virtual environment were ambiguous, participant responses were distributed between Strongly Agree, Agree, Disagree, and Strongly Disagree. For question 4 only two participants chose Agree, which indicates only a small portion of participants felt the virtual objects and robots were not similar to the physical ones.

5

Our results established that the virtual robot was easily controlled, especially in driving smoothly and turning. However, there are improvements required for the virtual robot. For example, the virtual robot must be able to automatically manipulate virtual objects (e.g., pick up a block for the negation task). Also, objects need to be modified to make them more closely resemble the physical counterparts.

It is important to stress that this study only evaluated the ease of controlling the virtual robot for non-disabled adults. Further investigation is needed in order to determine if children with and without disabilities have the same experiences using the virtual and the physical robot. If virtual robots can give similar benefits, then the virtual robot has the advantage that parents only need to download the free MS-RDS software express edition and do not need to buy a physical robot.

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