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I CAN TEACH THEM: THE ABILITY OF ROBOT INSTRUCTORS TO COGNITIVE DISABLED CHILDREN

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Abstract
Many studies have been published regarding ways in which to help students with cognitive disabilities. The strategies of repetition and digression from typical learning environments have been highlighted as important and efficient ways to assist students with cognitive disabilities. This study investigated if students with cognitive disabilities can learn house cleaning from robot instructors. Forty students participated in the experiment. In the control group, students participated in a training session with a human instructor. In our experimental groups, three sub-conditions were applied. Students participated in a training session with a robot teacher in addition to the regular training session. The results indicated that students who had a training session with a robot instructor significantly improved their functional knowledge and skills when compared to the students in the control group. In addition, the more repeated sessions the students had, the better their understanding. Both implications and future studies are discussed.

Keywords: robot instructor; cognitive disability; functional knowledge; functional skills; human-robot interaction

Introduction

As social robots continue to be developed, their adaption for educational use has been discussed, particularly for children with disabilities and for the elderly. Some avenues have already been explored, including

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learning social interaction skills (Robins, Dautenhahn, Te Boekhorst, & Billard, 2005), second-languages (Han & Kim, 2009; You, Shen, Chang, Liu, & Chen, 2006), history (Park, Kim, & del Pobil, 2011), and mathematics (Ponte, Zaslavsky, Silver, de Carvalho Borba, van den Heuvel-Panhuizen, Gal, Fiorentini, Miskulin, Passos, Paris, Huang, & Chapman, 2009). Based on these previous studies, it is believed that social robots can serve as a powerful and efficient learning tool.

Park et al. (2011) reported that robots can be used in educational settings instead of a human teacher. Robots motivate students to learn via similar delivery methods as those used in traditional education settings. Social robots can make humans feel comfortable and stabilized (Nie, Park, Marin, & Sundar, 2012). Communication using various modalities also encourages users to interact with social robots to improve their knowledge and abilities. Children with cognitive disabilities in particular can improve their social interactive skills and communication methods by interacting with robots through actions such as touching and scrubbing the robots (Cho, Kwon, & Shin, 2009; Cho & Shin, 2011).

Objectives

Therefore, this study aims to investigate whether children who had cognitive disabilities were able to learn specific skills by spending time with robots. We selected the specific skill of house cleaning because it is one of the most important areas of knowledge for daily living (Astrom, Aspund, & Astrom, 1992; Folbre, 1986). For example, learning to clean may increase an individual’s independence and enhance their social skills; children can even learn cleaning and self-catheterization skills. We hypothesized that learning from robots could provide efficient learning for children with cognitive disabilities. Previous studies that have incorporated social robots have already reported the positive effects of interactions between robots and children (Cho & Shin, 2011; Kanda, Hirano, Eaton, & Ishiguro, 2004; Robin et al., 2005; Scassellati, 2007; Werry, Dautenhahn, Ogden, & Harwin, 2001). Learning house cleaning from robots can afford lots of advantages for children who have cognitive disabilities, most notably because the setting is different than traditional educational settings, such as a classroom environment with a human teacher.

Learning from robots is multimodal and encompasses techniques similar to those experienced with a human teacher in the delivery of functional knowledge and skills. The robot even mimics the steps and motions of a human (Billard & Mataric, 2001; Breazeal & Scassellati, 2002; Nakazawa, Nakaoka, Ikeuchi, & Yokoi, 2002; Park et al., 2011). These settings engage students in live, fresh and user-friendly experiences. Students gain knowledge and skills from the robots via both explicit and implicit methods (Ritterfeld & Weber, 2006).

Robots can be used repetitively without danger, which is an advantage over human teachers who may experience fatigue. For children with cognitive disabilities, repetition in teaching and learning is one of the most efficient and important methods in educational settings, and robots can provide consistent and continuous interactions with these children. For example, Horn (1991) indicated that children with cognitive disabilities spontaneously repeated playing an educational video game (via augmentative and assistive communication devices) more than 30 times. Repeating an activity helps students learn functional skills and gain knowledge successfully and efficiently. Additionally, increased exposure to knowledge provides gains and advantages for students' memory and recall (Cacioppo & Pretty, 1979; Cunningham & Stanovich, 1991). In traditional education settings, these types of interactions are not likely due to time and resource constraints. For example, if a teacher has to teach more than two students, no students receive individual attention. However, a robot teacher never tires and may repeat information or commands endlessly if the child requires such actions (Park et al., 2011).

The most significant advantage of learning from robots is the tendency of positive acceptance and motivation. Cho and Shin (2011) provided evidence that cognitive disabled children tend to accept social robots more readily than other kinds of toys, agents and even humans. Because knowledge and skills are sometimes relational and definitions and theories are not clear, a learning activity can be extremely difficult for cognitive disabled children who sometimes operate with a very limited working memory and poor concentration (Hesketh & Chapman, 1998; Genter, 1981; Talmy, 1985). Therefore, a tendency toward positive acceptance may be helpful when teaching cognitive disabled children.

Based on previous studies of the effects of robot teachers and instructors on learning settings, this study focused on whether children who had cognitive disabilities were able to learn house cleaning functions from robot teachers. Few studies have been conducted regarding whether social robots are effective for teaching functional and essential skills to cognitive disabled children. Therefore, this study may contribute to the positive potential of robot instructors for cognitive disabled children who have limited attention, perseverance and learning abilities.

Methods

Participants

Forty cognitive disabled students were recruited from three special schools in South Korea. All students were of similar socio-economic status. The control group included 10 students, and the remaining 30 students were assigned to the experimental conditions. All students and schools agreed to participate voluntarily with no rewards or compensation. Students' ages and intelligence quotient (IQ) scores were required to be standardized for the experiment. All students were asked to answer questionnaire items (with their teachers' assistance) to assess their degree of intelligence (Yum, Park, Oh, Kim, & Lee, 1992). Intelligence was classified into four levels (Table 1). The age and IQ of all groups were matched as closely as possible based on the average of each IQ level. The demographic profiles of the students in this study are shown in Table 2. None of the students had prior knowledge of the robot and had never met the robot before the study.

Table 1. Scales of standardized intelligence scores

IQ levels	Range (Mean)
IQ in none limit (Normal)	Higher than 70
Mild cognitive disabilities (Mild)	60~69 (64.5)
Moderate cognitive disabilities (Moderate)	45~59 (52.0)
Severe cognitive disabilities (Severe)	Lower than 44 (about 40 in this study)

By using the average of each IQ level, the age and IQ degree of all groups were controlled as similar as possible. The demographic profiles of the students in this study are shown in Table 2.

Table 2. Demographic profiles of the students in this study

Condition	Age		IQ levels				
	Mean (SD)	Range	Mean (SD)	Normal	Mild	Moderate	Severe
Controlled (10 students)	13.2 (2.57)	10 ~ 18	50.9 (9.03)	0	2	5	3
Single time (10 students)	13.7 (2.63)	10 ~ 18	51.5 (10.17)	0	3	3	4
3 times (10 students)	12.9 (2.13)	10 ~ 17	51.7 (9.94)	0	3	3	4
No limit (10 students)	13.7 (2.16)	11 ~ 18	50.4 (9.71)	0	2	5	3
Total	13.4 (2.32)	10 ~ 18	51.1 (9.35)	0	10	16	14

Design

Pre- and post-tests with a quasi-experimental approach design were conducted (Shadish, Cook, & Campbell, 2002). This study included four groups. The control group did not have a session with a robot. Instead, it had a regular study session with a human teacher, who was an expert in special education with 15 years of experience. She taught house cleaning knowledge and skills for a week (every week for 30 minutes each day).

The students in the control group participated in the 15-minute regular study session for three consecutive days (twice per day). Thus, the students in the control group had six study sessions. On the other hand, the experimental groups' students took part in a session with a robot instructor for 15 minutes. It means that they each had two training sessions from both the human and the robot. We varied the duration and frequency of the robot training sessions as follows: a single session per day, three sessions per day, and no time limit with two a minute rest period. In the single and three session conditions, the robot acted as the teacher during one and three repetitive sessions per day, respectively. In the no-limit condition, the robot repeatedly played the instructions as much as a student desired. No group had previous experience studying or understanding house cleaning knowledge and skills.

Two tests were conducted in this study. Functional knowledge of house cleaning was assessed with verbs and behavioral motions. Verb and imitative motions play crucial roles in studying and learning new tasks. For example, when a student is asked to "sweep the room clean", he/she should understand both the meanings of "sweep" and "clean", as well as the corresponding physical actions such as how to manipulate a broom. Understanding verbs and behavioral motions is important for students' daily lives and tasks. Previous studies have indicated that knowing verbs and sentences in specific fields is helpful for various advanced tasks of daily living (Banda & Dogoe, 2011; Lancioni et al., 2011; Mechling, Gast, & Fields, 2008).

Appratus and Materials

In the human-instructor condition, an experimenter taught the participants with cleaning tools and a desktop computer connected to a VIM projector. In the robot-instructor condition, Nao, a humanoid robot, stood alone and posed as an instructor. To minimize the effect of the robot's other characteristics, including voice and gestures, this study used an audio file recorded by a human teacher for the robot. The robot's gestures were also adapted from those of a human teacher. The robot had 25 d. f. Supported software was used for manipulating Nao's motors, sensors, voices, and reactions. The software, Choreograph, was programmed and composed of Python, C++ and a graphic user interface. The robot was controlled by the experimenter who was located in an observation room, but could view the experimental environment via a two-way mirror.

Description of the House Cleaning Session

The cleaning training session was composed of five sub-sessions. In each given session, an experimenter observed every activity of the instructor and student. First, the instructor and the students introduced themselves. Second, all of the steps of house cleaning were explained by the instructor via a desktop computer connected to a VIM projector. Third, the instructor showed examples of each step of the house cleaning using motions and gestures. Fourth, the instructor made the students imitate their motions and gestures. Fifth, the student was debriefed and thanked. Each training session was administered in the same room, and students all used the same desk.

Development of pre-test and post-test

All tests were conducted in a sound-attenuated and bright room. A video camera was installed to record the students' behaviors and was placed facing the students.

Pre-test

The pre-test was administered before the training session on the first day. The test consisted of six verb and six picture questions. In the verb questions, an experimenter showed four selections (pictures) for one verb related to house cleaning knowledge and skills. The student was asked to select the one whose picture matched the verb question. In the picture questions, an experimenter showed four selections (sentences) for one picture related to house cleaning knowledge and skills (*e.g.* Figure 1). Then, the student indicated selected the sentence that matched the question. Using the same rules, six verbs and six pictures were presented. Each question was worth 1 point.

Figure 1. An example of pre-test

Training session from the robot

The training session with the robot began immediately after the training session with the human teacher in the experimental groups. The students, observer and the robot instructor were left alone to avoid any other disturbances.

Post-test

All groups participated in a post-test that followed the same procedure as the pre-test. The post-test was administered two days after all of the training sessions were finished.

Results

Robot Instructor for learning skills

The robot instructor was helpful for cognitive disabled students to learn verbs, functional knowledge and skills. All groups in this experiment improved their knowledge and skills between the pre-test (M=5.43, SD=1.85) and the post-test (M=7.05, SD=1.60). A 2 x 4, two-way mixed analysis of variance was conducted to compare the groups (between-subject variables) and the pre and post-test results (within-subject variables). The groups did not differ significantly (p=.312). However, the interaction between the groups' and change in scores was significant (F(3, 36)=7.09, MSe=2.31, p<.001). This finding suggests that the repetitive exposure that the participants received from the robot was more efficient in improving their functional knowledge and skills than the relatively lower amount of exposure provided by the human teacher. Figure 2 shows the scores from the pre-test and post-test for all groups.

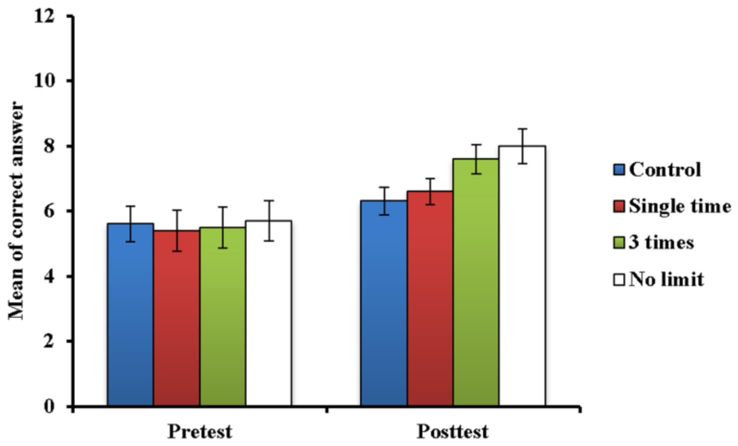

Figure 2. Functional knowledge and skills improvement from pre-test to posttest based on the groups

IQ Levels Most Affected by the Robot Teacher?

The students' IQ levels showed an improvement of functional knowledge and skills at the end of our study. Although all groups' scores increased, students with moderate cognitive disabilities (n=16, the average difference between two test scores: 1.69) and severe cognitive disabilities (*n*=14, the average difference between two test scores: 2.00) achieved significantly better improvements than those with mild cognitive disabilities (*n*=10, the average difference between two test scores: 1.00, $F(2, 37)=3.49$, $MSe=1.48$, $p=.041$, Figure 3).

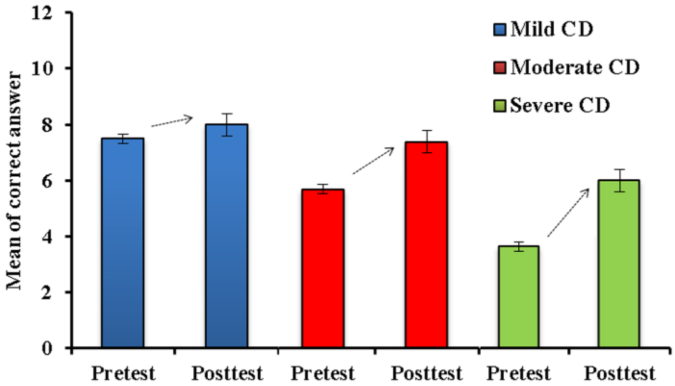

Figure 3. Functional knowledge and skills improvement from pre-test to posttest based on IQ levels of students

In order to measure the effect of the increase in score between the pre-test and post-test, Cohen's d was calculated using the same procedure as in the study by Dunlop and colleagues (Dunlop, Cortina, Vaslow, & Burke, 1996). Students with severe cognitive disabilities had an effect of 1.24. The students with moderate cognitive disabilities had an effect of 0.84. However, students with mild cognitive disabilities had an effect of 0.39. This indicates that students with severe and moderate cognitive disabilities can expect more benefits from robot instructors than those with mild cognitive disabilities.

Conclusions

This study aimed to investigate the effect of a robot instructor for cognitive disabled students on learning specific functional knowledge and skills related to house cleaning. The results of the experiment indicated that cognitive disabled students who had a training session with the robot instructor experienced better results than those in the control group. The robot was more beneficial for students with severe and moderate cognitive disabilities than it was for those with only mild cognitive disabilities. Our findings also provide evidence for the theoretical value of r-learning (robot-learning) in special education research. Because most cognitive disabled students have trouble learning and practicing, our findings suggest the great potential of using a robot teacher for these students (Cho et al., 2009; National Information Center for Children and Youth with Disabilities, 2009).

Our study also has important implications for researchers and practitioners of special education. Not surprisingly, previous studies have indicated that learning and practicing something were too difficult to be expected from cognitive disabled students. This indifferent tendency can be amplified when the students interact with human teachers, who have typical and traditional characteristics that can make students bored and irritated. Additionally, cognitive disabled students are more likely to have communication difficulties and may struggle with matching verbs and objects (Brock, Norbury, Einav, & Nation, 2008). This study confirmed that robots can successfully serve as an alternative teaching method for cognitive disabled students.

There are some limitations to the present study. First, we did not consider the effects of perfect repetitive exposure to educational material. That is, students in the experimental groups had more opportunities to spend time with the learning materials than did those in the control group. Second, the size of our sample was small, making it difficult to generalize our findings to a larger population. Third, all students were recruited in South Korea. Students in South Korea tend to be more introverted and calm than those in North America or Europe, which could have affected our results. Lastly, we did not consider the familiarity or any preconceptions or preferences that our participants may have had toward the human and robot instructors.

Future studies are needed to investigate the following topics. First, we do not know exactly what factors positively motivate or encourage cognitive disabled students to gain functional knowledge and skills effectively. Second, we did not confirm whether students used the functional knowledge and skills from the training session in their home after the study. Third, one of the most widely used humanoid robots was used as a robot instructor in this study, but many social robots may be suitable for education and service. Thus, future studies should explore other robots in the delivery of functional knowledge and skills even though they may not be as humanoid as the robot used in our study.

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