A Hands-Off Assistive Robotic Educational Intervention Strategy for Children with Attention Deficit Hyperactivity Disorder

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ABSTRACT
This paper describes a feasibility study of using an autonomous and socially assistive mobile robot to aid children with attention deficit hyperactivity disorder by providing encouragement, monitoring, and increasing the children's attention and academic productivity.

Categories and Subject Descriptors
K.4.2 [**Computers and Society**]: social issues; J.4 [**Social and Behavioral Sciences**]: psychology; I.2.9 [**Artificial Intelligence**]: robotics

General Terms
Human Factors, Experimentation

Keywords
Human-robot interaction, embodiment, social robots, psychology, educational intervention strategy, attention deficit hyperactivity disorder

1. INTRODUCTION
Attention deficit hyperactivity disorder (ADHD) is a condition that that affects 3% to 5% of school-age children or approximately 2 million children in the United States [7, 8]. It is estimated that at least one child will have ADHD in a class size of 25 to 30 students [8]. These ADHD children are faced with negative behaviors that include low self esteem, social and academic failure, substance abuse, and a possible increase in the risk of antisocial and criminal behavior [2]. Early intervention will reduce these risks and provide long-term effects to improve the children's lives. A combination treatment of medical, educational, behavioral and psychological intervention strategy has been shown to be the most effective in treating children with ADHD [2, 8]. If an educational, behavioral and psychological intervention strategy would prove effective, prescription doses would be less necessary [8]. This in term can reduce the undesirable side effects of medication. This work aims to develop a socially assistive mobile robot to provide an effective educational intervention strategy for elementary school students with ADHD. It also aims to assist teachers in helping the students with ADHD. Teaching ADHD children requires special training and individualized attention from the teachers. However, due to the shortage of special education teachers and ADHD students being placed in the same classrooms with average students, regular teachers' attentions make up for less than what an ADHD student needs. The human-robot interaction is not only going to provide one-on-one attention needed by the student with ADHD, but also monitor the student's progress and increase his or her attention and academic productivity. Overall, this work aims to use hands-off assistive robotic by implementing the mobile robot, Eddie, to accomplish the following goals: provide an educational intervention strategy through human-robot interaction, provide one-on-one attention needed by a student with ADHD, monitor the student's progress in the absence of a teacher, and determine the effectiveness of the proposed educational intervention strategy in terms of improving the student's scores.

2. RELATED WORK
Beyond the traditional methodologies, many software-based systems for diagnosing and coping with ADHD exist which include Rizzo et al.'s virtual reality system, the virtual classroom [13]. The virtual classroom is used as a tool for diagnosing attention disorder. It is visible through a head-mounted display that blocks everything in the outside world and several distractions are introduce in the virtual environment to test attention. The system also tracks the head, arm, and leg movements using three position-and-orientation magnetic trackers from Ascension Technology. Rizzo et al. also want to create a virtual environment conducive for the ADHD student's learning. In contrast, this requires modification of the environment and physical interaction. It may also cause both eye strain and motion sickness, which are typical problems of viewing animated three dimensional video images [14]. In contrast, a hands-off assistive human robot approach is a better alternative as it provides a safe way of interacting with the ADHD child through social, rather than physical, interaction. The goal with this work is to change a child's behavior or improve his or her behavior through socialization. This can be done by enabling the child initiate contact with the robot and vice versa. It also promotes social awareness as the student is not immersed in his or her own world as in the virtual environment. This is accomplished by enabling the student to interact with other people, such as the teacher, while interacting with the robot. An advantage of using a robot is embodiment. Embodiment of the assistive robot, Eddie, enables a robot to move and engage the child more effectively than for example having the child look through a video game on the computer, which is essentially what Rizzo et al.'s approach can be seen as.

Many socially interactive robots are developed to serve children as educational tools [6]. They are used for children with mental illness such as autism. Michaud and Caron implemented a mobile robotic toy Roball to not only entertain children but also help children with autism [5]. Assisting autistic children with robotic toys and experiencing success are not uncommon in these applications [10, 11, 12]. Robotics applications for children with ADHD currently do not largely exist, if they exist at all. However, a feasibility study is conducted in this research to help determine whether a socially interactive robot can be tailored for children with ADHD and serve as an educational intervention strategy to help them make progress in academics.

3. SYSTEM DESIGN

The robot system, Eddie, consists of an ActivMedia Pioneer 2-DX mobile robot with a SICK LMS200 scanning laser range finder, a Sony pan-tilt-zoom camera, and a primary battery power. The laser range finder enables the robot to locate the student wearing a reflective fiducial on his or her calf. The sonar is used in conjunction with the laser range finder to enable the robot to autonomously navigate safely around obstacles in the environment. The pan-tilt-zoom camera is mounted on the robot to provide vision and color blob detection from the student in order to facilitate the student-robot interaction. This form of interaction is chosen in order to avoid the problems associated with speech recognition and to avoid possibly frustration from having the student repeat many times. The colored fluorescent flash cards are also used intentionally to assist the student in organizing the ways in which he or she can interact with Eddie.

Additionally, a robot interface is provided through a 2GHz Pentium M laptop with a 64MB ATI video card running Ubuntu Linux. The 15” LCD screen on the laptop is used to display a video using a simple and portable media player called FFplay. The interface is meant to be very entertaining to capture the student's attention; therefore, it consists of 2D animated cartoon character illustrated in figure 1 with pre-recorded speech. Pre-recorded human speech has been found to be very effective for motivating users through human-robot interaction [3].

Eddie’s physical appearance is robot-like without any dress-up like in [15] to appear as one of the robots in Star Wars. The goal of the physical appearance is to make the student feel comfortable with the friendly and educational robot toy and be willing to interact with the robot.

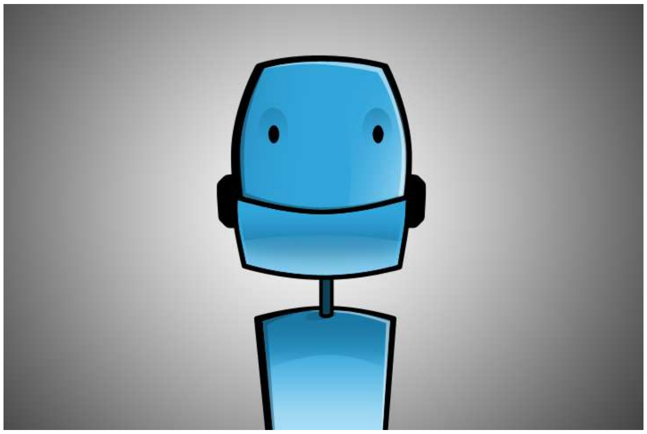

Figure 1. The interface of the assistive mobile robot, Eddie.

The behavior-based approach will provide the underlying architecture of the robot. There are three main behaviors. At the lowest level, the obstacle avoidance behavior is found. It uses sonar to detect obstacles. Finding the user is another behavior located at the next level. The robot stays in place while it rotates to locate the fiducial fitted on the user using a laser scanner. The interaction design behavior deals with the interface display. It is divided into two separate modules, one to obtain the problem for the game interaction, and the other one to obtain the exercise activity for the physical interaction.

4. INTERACTION DESIGN

Part of the challenge in designing an interactive system for children with ADHD is that it has to be very entertaining and capture the children’s attention and imagination. This work focuses on verbal prompting and encouragement. The target student of this work is an ADHD elementary school student. He or she can be doing some exercises from a book, a computer, or other alternative forms of learning. For the purpose of this work, an educational off-the-shelf product that is specially developed to supplement an elementary school level Math curriculum is used because of its automated scoring process, as well as its ability to keep track of the length of time consumed by the student. The ADHD student doing his or her work may sometimes have difficulty following instructions or paying attention. He or she may not feel comfortable with seeking assistance from the teacher. It is suggested that using an educational toy robot, such as Eddie, to interact with the student on a one-on-one basis can indirectly help the student build his or her self-esteem. This is accomplished by engaging the student to do some physical exercises or answer relevant questions such as elementary Math problems like addition, subtraction, multiplication, and division [1]. In this case, the robot is serving as a socially competent peer and a mentor for the ADHD student. The robot will monitor the student’s progress by making sure he or she is on task. At random intervals, the robot will initiate contact with the student by asking to play a game. The student will also have the opportunity to initiate contact with the robot by using fluorescent colored flash cards to get the robot’s attention; this element of physical interaction will provide a subtle way for the ADHD student to develop social skills. In general, the series of exchanges taking place in all parties culminate as solutions in improving the student’s educational and social well-being.

Two types of interactions are provided by the robot system: game playing and exercise activity. Each is described in detail.

4.1 Game Interaction

Game interaction can be used to easily determine whether the student is being on task or understanding the exercises he or she is assigned to do by the teacher. The game playing interaction consists of solving elementary Math problems. Different types of problems from different subjects can easily be used. The robot will try to assess the student's learning in three levels: beginning, intermediate, and advanced. The level of the problem difficulty is chosen at random to test the student's understanding of the topic. After a problem is chosen, the robot visually displays an illustrated image on the 15" screen indicating the problem, and the true or false question surrounded by squares with the color corresponding to the fluorescent colored flash card. The student will have a fixed time of 5 minutes to think of a solution and use the fluorescent colored flash card corresponding to the possible solution. The robot praises the student for the correct solution; otherwise it encourages the student to do better next time and offers the option for the student to play again by asking the student to use the fluorescent pink flash card.

4.2 Physical Interaction

One suggested classroom tip for teachers is to incorporate more frequent breaks for students with ADHD. Exercising activities enable the student to engage in physical activities to release his or her excess energy and refocus on his or her task. A fluorescent green colored flash card tells the robot the student wants to exercise, so the robot randomly selects one of the exercise videos for the student to perform. The student is then asked to follow a 30 seconds to 1 minute exercise routine such as stretching, flexing, and jumping.

5. EVALUATION

In order to conduct a feasibility study of the educational intervention strategy for children with ADHD, experiments were carried out in a controlled environment at the University of Southern California's Interaction Laboratory. While the goal is to have actual children diagnosed with ADHD evaluate the hands-off assistive robotic system, there was not enough time to gather ADHD students. In this case, normal or non-diagnosed students were used to test pilot the prototype system to gain valuable feedback before conducting the experiments with ADHD children. Specifically, each experiment was divided into two sessions. The first session was performed with the robot interaction and the second one without the robot interaction. It is noted that the sequence of the sessions affect the results. Thus, the first three students started without the robot interaction, while the last three students started with the robot interaction. In both cases, a questionnaire was also administered to the students at the end of the study.

5.1 Experiments

The evaluation of this system involved two sessions: student-computer and student-robot. For the first session of each experiment, the student was asked to solve some problems on the educational Math software installed in a computer. The difficulty of the Math problems ranged from easy to hard level of addition, subtraction, division and multiplication. The first session involved the robot interaction. The experimenter fitted the student with a laser fiducial and gave a pink and a green fluorescent flash card to interact with the robot. The student was told to use the flash cards whenever he or she needed a break from the task. The student was also told to use the pink fluorescent flash card to signal the robot to play a game with the student and the green fluorescent flash card to signal the robot to display an exercise activity. In these two types of interactions, the Math level problems and the exercise activities were chosen at random. The student was expected to initiate the contact when he or she wants to take a break from the computer by using a fluorescent colored flash card to signal the robot to approach him or her. By having the student initiate the contact with the robot was a subtle way to help develop social skills. After each interaction with the robot, the robot asked the student to return to his or her task on the computer or continue with the interaction. If the student did not initiate any contact with the robot, the robot would approach the student and ask him or her to play a game at random intervals. This process enabled the robot to monitor the student's progress and check whether the student is on task or understanding the exercises. Whenever the student interacted with the robot, the robot also kept track of the problems solved correctly and the time taken during each interaction.

For each subsequent human-robot interaction, if a fluorescent pink colored flash card was detected, the robot chose a Math problem based on the performance of the last interaction for the student to work on. A similar problem was chosen when the student solved the previous problem incorrectly, otherwise a random problem was chosen. This process enabled the student to practice solving similar problems and to improve. If the student continued the task for 10 minutes, the experiment asked the student to stop. The results of the student's performance on the computer were recorded by the experimenter before administering the second session.

Following the first session, the student was asked to perform the same task as in the first session, but without the robot interaction. The student was able to stop whenever he or she was bored or tired with the task. If the student continued with the task, the experimenter asked the student to stop after 10 minutes. The results of the student's performance on the computer were recorded by the experimenter.

After the last session, the student was asked to complete a survey. The survey included questions that determined whether the student found the intervention strategy useful.

5.2 Results

Six non-diagnosed ADHD USC students participated in the evaluation of the system. They were in their early to mid twenties. Three of which were females. On the average, all the students engaged or interacted with the robot about equal number of times. The female students were, however, more inclined to perform the physical exercises when requested by the robot. The male students only laughed or stared at the exercise videos being displayed. The physical activities were targeted for children and the children in the exercise videos were young girls. One student indicated that she felt silly performing the exercise while two of the students indicated that the children were cute. Overall, the exercise videos appealed to the students at a superficial level but only female students were engaged in the process.

For the computer interaction of the experiment, students chose the level of difficulty of the problems to solve. Some of them decided to solve English related problems such as analogies because they found it more challenging. The experimenter did not limit the task to solving only Math problems. Again, the software was intended for children in elementary school, but the students still found it fun and sometimes even challenging when the level of difficulty was set to the highest level. The students generally solved similar problems in terms of level of difficulty while interacting with the robot and without the robot as illustrated in figure 2.

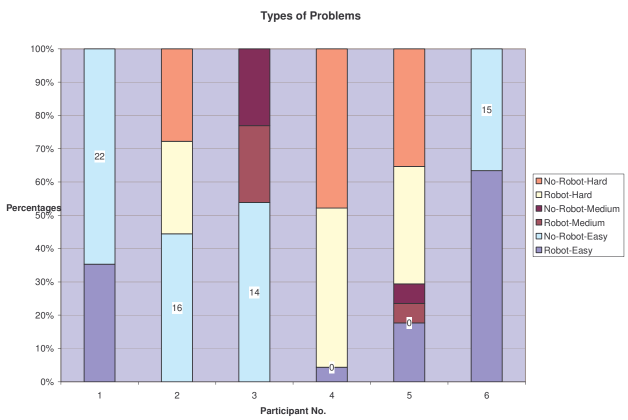

Figure 2. The level of difficulty of problems solved by students.

From the analysis of the data in figure 3, the students solved more problems using the computer without the robot interaction. Again, these students do not have ADHD. The ADHD students may not perform as well. But the current results can provide good comparisons for future experiments with ADHD students. On the average, the students performed better while interacting with the robot as illustrated in 4. One student, who solved the same number of problems while interacting with and without the robot interaction, indicated that she could at least relax when she was interacting with the robot. During the recorded experiment session without the robot interaction, the same student was observed to be looking for the robot when she was bored.

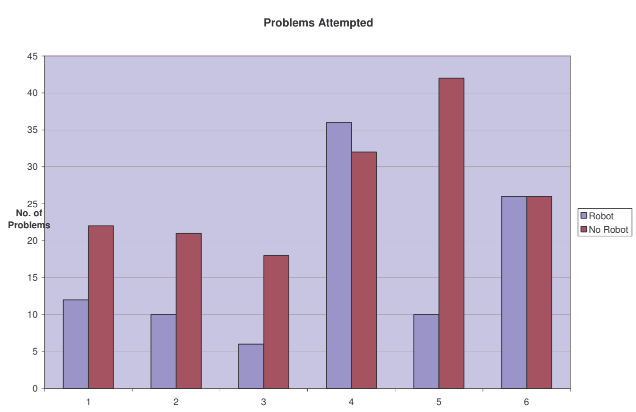

Figure 3. The number of problems attempted by the students while interacting with and without Eddie.

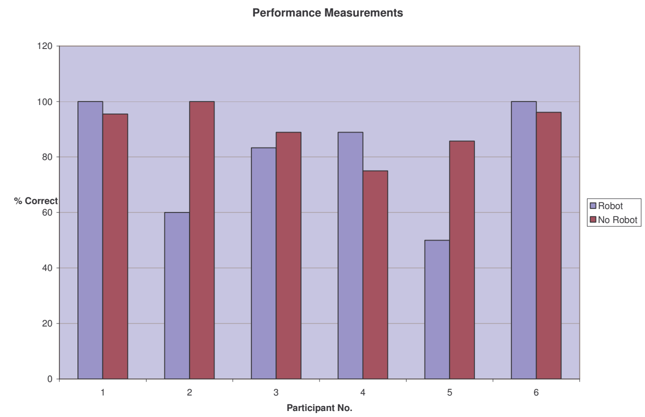

Figure 4. The percentage of problems solved correctly by the students while interacting with and without the robot.

One emergent behavior resulted from this system design as later observed during the human and robot interaction. One of the exercise activities involved having the student spin. The student decided to rotate while sitting down on her chair. After she finished spinning or rotating, the robot rotated around before resuming interaction with the student. This behavior resulted from the activation of the finding user behavior when the robot lost contact of the student's fiducial fitted on her calf, but the student thought the robot was spinning along with her and smiled.

Table 1. Survey results of the six test subjects

Questions	A lot	Somewhat	No
Is robotic educational intervention strategy for ADHD children a good idea?	3	2	0
Did the robot help you refocus in your task?	0	3	3
Did the robot make it more enjoyable for you to perform your task?	1	3	2
Did you like interacting with the robot?	2	4	0
Did you feel you can solve more problems as a result of interacting with the robot?	0	3	3

Table 1 summarizes the data collected from the student surveys. The students generally think using Eddie as an educational intervention strategy for ADHD children is a good idea. They also like interacting with it, but it is still at its prototype stages. It needs some improvement in terms of initiating the interaction with the student and engaging the student to perform the physical exercises. Also, one of the major disadvantages of Eddie was that the video frame rate of the videos was not synchronized with the audio. This was due to a video compression problem at different frame rates.

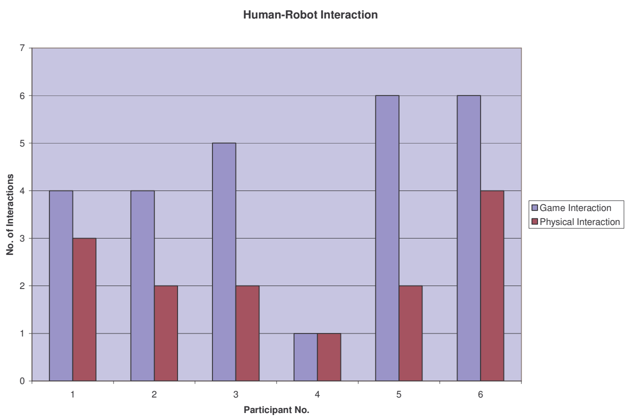

Figure 5. The number of times and the types of interaction the students were engaged in with Eddie.

6. DISCUSSION

The results in these experiments provide a basis for comparing future results from experiments with children with ADHD. Eddie appealed to mostly female students because of the system design's interface. The system's interface used a friendly and an animated robot face. The exercise videos were performed by young girls. In the next prototype of Eddie, some elements will be incorporated in the design of the next system to engage the male students. The students in the experiments generally wanted to interact with the robot for short term interactions and continue with the task. Even though the problems asked by Eddie were easier than those chosen by the students on the computer software, the interaction provided by Eddie enabled the students to be productive while completing their tasks as opposed to looking around and getting distracted in a nonproductive way. This was observed from one of the students during the experiments. Videos of the experiments can be found at http://robotics.usc.edu/~changjen/projects/cs584/.

Figure 6. Eddie interacting with the student using color blob detection.

Not all students in the experiments were alike in the experiments. Some of them liked more challenging problems to work on while other students liked problems that were just right given their abilities to solve the problems. Eddie was limited to short term interactions with the students. In future improvement of the system, while the educational software can remain the same, the interaction design of Eddie would need to be able to adapt to different students' learning abilities to keep it more interesting for the students in order to sustain long term interactions.

7. CONCLUSIONS AND FUTURE WORKS

This paper described an implementation of a hands-off assistive robotic educational intervention strategy for children with ADHD. It offered a way for ADHD children to release their excess energy in a productive and effective way and return to their task. A hands-off robotic educational intervention strategy can minimize the need for medicinal use and serve as a good treatment for children with ADHD through social, rather than physical, interactions.

Future work involves enhancing and evaluating the system in several ways:

- Dynamic adaptation of the interaction modes in response to the student's behavior and learning models of the student.
- Dynamic support for other elementary-level subjects.
- Testing the effectiveness of the system with diagnosed ADHD children.
- Better detection system to initiate interaction and engage the student in physical exercise by using motion capture suit or vision tracking to detect behavioral response [16].
- Determine the system's effectiveness by comparing it to other educational intervention strategies.

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