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Virtual Reality for the Treatment of Autism

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Abstract. Autism is a mental disorder which has received attention in several unrelated studies using virtual reality. One of the first attempts was to diagnose children with special needs at Tokyo University using a sandbox playing technique. Although operating the computer controls proved to be too difficult for the individuals with autism in the Tokyo study, research at the University of Nottingham, UK, is successful in using VR as a learning aid for children with a variety of disorders including autism. Both centers used flat screen computer systems with virtual scenes.
Another study which concentrated on using VR as a learning aid with an immersive head-set system is described in detail in this chapter. Perhaps because of the seriousness of the disorder and the lack of effective treatments, autism has received more study than attention deficit disorders, although both would appear to benefit from many of the same technology features.

1. Introduction

Autism is a pervasive developmental disorder characterized by severe impairment in social, communicative, cognitive, and behavioral functioning [1,2]. Affecting two to five persons per 10,000, the disorder has devastating long term effects. As adults, about two thirds of persons with autism remain severely disabled and unable to provide even basic personal care. While there are inconsistent profiles across individuals diagnosed with autism [3,4], three commonly found traits involve abnormal response to input stimuli, lack of human engagement, and the inability to generalize between environments. It is postulated that one cause of these responses may be the inability to synthesize input stimuli [5]. A profound abnormality in the neurological mechanism which controls the capacity to shift attention between different stimuli may exist, leading to distorted sensory input and over selectivity in attention to input stimuli [6,7]. An inability to recognize and process similarities between different scenes may also account for the lack of generalization skills. This results in rigid, limited patterns of action and compulsive or ritualistic behaviors.

Attention deficit disorder (ADD) and attention deficit hyperactivity disorder (ADHD), while exhibiting different symtomology from autism, shares the problem of difficulty in managing normal input stimuli. Where autism is rare, ADD and ADHD are prevalent in children. Present estimates vary, but one source claims there are over 2 million ADD/ADHD children in the US, half of whom carry the problem into adulthood [8]. Over 90% have difficulties in school, with 20-30% repeating a grade before high school and 40% requiring special education programs. ADD and ADHD have been linked to delinquency, and may develop into antisocial personality disorder in adulthood [9]. Children with these disorders are inattentive and have trouble with normally repetitive tasks. They are easily distracted and bored, often looking for more stimulation, and can be very demanding and self-centered. Although the problem is chronic, it is not evident in all circumstances, but may appear spontaneously, leaving the child unmanageable for short periods of time. It is postulated that this problem may also be neurological, caused by under activity in areas of the brain dealing with inhibition, attention, and sensitivity to reward [10]. These children respond well to positive, consistent, continuous feedback, and appear to need a different stimulation than a normal child to maintain interest. However, if there is too much varying stimulus in a room, they can experience attention problems. Teaching children with attention deficit disorders requires well structured, responsive, individualized training, just as it does for autism.

2. Why VR May Be Useful

With autism and attention deficit disorders The strengths of VR appear well matched to the needs of learning tools for children with autism and attention deficit disorders. Features useful in mastering interaction with the real world and which are attainable with VR include:

1. *Controllable Input Stimuli*: Virtual environments can be simplified to the level of input stimuli tolerable by individual. Distortions in size and character of the components of reality can allow matches to the user's expectations or abilities. Distracting visual complexity, sounds and touch can be removed and introduced in a slow, regulated manner. For attention problems where the child may be easily distracted and bored, the level of stimulation and interaction can be raised to maintain individual attention levels.
2. *Modification for Generalization*: Minimal modification across similar scenes may allow generalization and decreased rigidity. This is particularly significant for autism. A person taught to cross a virtual street in one scene might generalize to another street scene if the differences are reduced until the similarities are recognizable. An example might be two streets which are identical except for one building color. Differences could be increased slowly to teach cross recognition.
3. *Safer Learning Situation*: A virtual learning world provides a less hazardous and more forgiving environment for developing skills associated with activities of daily living. Mistakes are less catastrophic and overall stimuli can be reduced or increased. Environments can be made progressively more complex until realistic scenes to help individuals function safely and comfortably in the real world.
4. *A Primarily Visual/Auditory World*: VR presently stresses visual and auditory responses rather than other senses such as touch. Particularly with autism, sight and sound have been effective in teaching abstract concepts [11]. Individuals with autism indicate their thought patterns are primarily visual [12].
5. *Individualized Treatment*: Individuals with these disorders vary widely in their strengths and weaknesses. Each individual may even demonstrate tremendous variation in skills and behavior between different days [13]. Given this non-homogeneity of abilities, an individualized approach to placement and training based on a careful, personalized assessment is essential. Computers allow dynamic environments to compensate for changing patterns of development and inconsistent responses.
6. *Preferred Computer Interactions*: The complexity of social interaction can interfere when teaching individuals with social disorders. Establishing influence over the child is an often difficult first step where human interaction can be so disruptive that learning is not possible. These children respond well to structure, explicit, consistent expectations, and challenge provided by computers. As early as 1968, computers were used to assist language development therapy with autistic children [14]. Advantages of computer learning aids have been reported in multiple studies for both autism and attention disorders [15,16,17]. PC and workstation computer systems now allow live video feeds

within virtual worlds, permitting children to learn basic social interactions in consistent, accepting way.

7. *Trackers*: The use of body and head trackers present other possible advantages. The physical activities of an individual can be monitored in a virtual reality, allowing the machine to adjust to a patient's actions. Since over half of individuals with autism never learn to communicate, this allows interactions in virtual scenes without verbal training from a teacher on more sophisticated hand controls. Also, an interesting match may exist between latency problems of trackers and abnormal vestibular functioning related to autism. Vestibular confusion appears to be less disturbing to individuals with autism, and in fact may be a positive reinforcer [18]. Sensory integration training interventions have been based, in part, on these vestibular responses [19].

3. Two Case Studies on Using Virtual Worlds as a Learning Tool for autism

Because of profound variations among people with autism and inconsistencies of response by any one individual from day to day, a case study approach using personalized world modification and assessment was selected for our original study on the value of VR as a learning aid for children with autism. Two autistic children, a seven year old girl and a nine year old boy, took part in the study which consisted of over forty virtual exposures during a six week period. This allowed re-verification of actions over a series of trials with each child. For safety considerations, no exposure was over five minutes.

Both children had been unequivocally diagnosed as autistic, based on test results, parent and therapist reports, behavioral observations and early history. Neither child was classified as high-functioning. The project was a collaborative effort between the North Carolina State University Computer Science Department and therapists from the Division for Treatment and Education of Autistic and other Communications handicapped CHildren (TEACCH) at the University of North Carolina at Chapel Hill School of Medicine. Also active in the tests were parents, siblings, and teachers of the children.

3.1 Project Design

The first part of the initial test was to train a child with autism to recognize and track a common object in a virtual environment, which in our trials was a moving car within a street scene. In the second phase the tests attempted to train the children to find an object in the environment, walk to it, and stop. Instructional training by therapists several months previous to our tests attempted teaching this skill to one of the subjects, with limited success. Eventually, the learned skills could lead to the ability to cross a street alone.

Both children were minimally verbal. They could use a few select words such as car and blue, but could neither speak nor understand many normal sentence structures. To avoid complex instructions or hand controls, short verbal instructions were used. Responses from the children were either one previously known word or performing the requested actions, such as turning their heads to find a car.

A ProVision 100 fully integrated VR system by Division Inc. was used. Software consisted of an object-oriented virtual reality development environment designed to create virtual worlds on the Division system. The tracker was a Polhemus FASTRAK. The headset was the Divisor made by Division with a field of view of 41 degrees vertically and 105 degrees horizontally, with 75 degrees per eye. Resolution was 345 horizontal by 259 vertical pixels. Because of extreme resistance to unfamiliar experiences shown by children with autism, familiar schedules, work, and play activities were introduced into the physical test area. Accustomed patterns from school were duplicated, with the introduction of short, original activities in the virtual helmet spaced between already accepted and familiar activities. Many children with autism, including the ones chosen for this study, object to hats or helmets being placed on their heads. The available VR helmet weighed approximately 8 pounds. The children were acclimated to a normal football or riding helmet while at home before the tests began. Older siblings of the children assisted in the tests by wearing the VR helmet and responding appropriately to the virtual environment while the parent attempted to have the autistic child watch, with varying success. Because the children were unable to verbally express problems or discomfort, helmet wearing was not forced when the child objected. Enticements such as M&Ms encouraged participation.

3.2 Virtual Environment Design

The virtual world was a simplified street scene consisting of a sidewalk and textured building shapes. All motion objects such as people, animals, and objects in the sky were removed. Periodically one car, whose speed could be changed, would pass the child standing on a sidewalk. The contrast was kept low in the scenes with gray being the dominant color. The low quality of the headset screens provided a less detailed environment automatically. The cars, the focal point of the test, were presented in bright, contrasting colors. Only car colors recognizable by the individual child were used, in one case this meant colors were limited to red and blue. The worlds were continually modified for each individual to take into account the dynamic response patterns between sessions.

3.3 Results

The results indicated an encouraging adaptation to the technology. One child immediately accepted the virtual helmet and immersed herself to the point that she identified cars and colors. The second child was more rigid and required three sessions, all within a fifteen minute period, to accept the helmet and respond to the scene. Once the helmet was physically accepted, both children would track the cars visually by turning their bodies and identifying the cars and their colors. The children repeatedly immersed themselves in the virtual scenes to a degree that they verbally labeled objects, colors of objects and tracked virtual moving cars. A STOP sign was attached to the hand controls and moved to different parts of the tracking area during the later tests. The children were asked to find the sign within the scene. This would appear in the virtual world as if the sign moved to different areas of the sidewalk. At times it was difficult to judge the sign's distance because of the lack of comparison cues. This may have contributed to difficulty in the final test sequence which involved stopping at the sign. Both children were able to turn and find an object in the virtual setting and to walk toward it. One child stopped when reaching the object, which was the new learning exercise.

4. Controlled Verification of VR Learning Benefits

4.1 The rationale

Although the initial research indicated a potential value in using VR with disorders which benefit from stimuli control, the work was not regulated enough to verify that the responses were truly new learned skills and determine if the skills translated to real world situations. The present phase is intended to help resolve these issues. The aims of this research are to build a prototype for a low cost virtual reality system that can be used in classrooms with autistic children, demonstrate the system's instructional potential by teaching object recognition, and establish if learning in a virtual environment generalizes to the classroom.

While there are many potential applications of virtual reality for instruction, we chose this application for several reasons. First, it is a simple task, well suited to level of sophistication now available in low cost virtual reality equipment. Second, we chose a task that taps a core deficit in autism--language [2]. Third, we chose a task that is part of an internationally recognized curriculum for autism [20] developed by TEACCH so that the task has been validated as important for students with autism and fits into an already established sequence of instruction. Object recognition is a rather basic task that does not tap the full potential of virtual reality, but this phase is designed to demonstrate that learning does occur in a virtual headset and that this learning generalizes to the real world.

4.2 Project Design

The research team involves therapists, educational experts, and computer scientists and is funded by NICHD, a section of the US National Institute of Health, as part of a business grant to make this technology more available to the public. The subjects in this investigation range in age from six to twelve and are receiving autism services in the classrooms where the tests are conducted. The equipment involves an off-the-shelf PC, free software available on the Web, and a low cost n-vision VR headset with a built in head tracker. The virtual environment consists of several objects which are displayed and manipulated in the headset.

The test plan is a variation of the multiple baseline across subjects lay out called a multiple probe design [21]. In a multiple baseline design of this type, baseline data are collected on all subjects prior to intervention. One subject is then targeted for the intervention while baseline data collection continues on the other subjects. A multiple probe design is a variation of this in which baseline probes are collected several times but not daily during the baseline phase for each individual. A multiple probe design is appropriate when subjects of the treatment are unable to perform the task at all [21, 22]. This design allows one to avoid requiring the subjects to repeatedly attempt a task for which they is not yet receiving instruction.

Although the tests are ongoing, initial results indicate an encouraging acceptance of the hardware by the children and an ability to learn the new objects in the headset. Proving the usefulness of the headset allows more sophisticated training in virtual environment where a presence might be significant, the child is unable to filter any outside distraction, or the training involves immersive scenes such as physically crossing a street. For many mid to high functioning children where the learning application is not complex, the flat screen VR interaction may be as useful and would provide a low cost generally available learning aid. Several present studies have established that VR interaction improves learning over more traditional computer programs, even when a flat screen rather than headset is used [23].

5. Conclusions

Autism and attention disorders involve abnormal stimulus response to the external world. Virtual reality offers the potential to regulate an artificial computer environment to better match the expectations and needs of individuals with these problems. The research described in this chapter as well as numerous studies going on around the world indicate that this regulating effect may be of value in helping these individuals learn to better react to their real world.

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