The Virtual Classroom: A Virtual Environment for the Assessment of Attention Processes in Children with Attention Deficit Hyperactivity Disorder

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Introduction

Digital Media Works and the Virtual Environments Laboratory at the University of Southern California (USC) have evolved a basic research and commercial application program aimed at developing virtual reality (VR) technology applications for the study, assessment, and rehabilitation of cognitive and functional processes. This work primarily focuses on the development of systems that address the needs of clinical populations with some form of central nervous system (CNS) dysfunction. These clinical populations include persons with cognitive and functional impairments due to acquired brain injury, learning disabilities and neurological conditions. The rationale for VR applications designed to serve these populations is fairly straightforward. By analogy, much like an aircraft simulator serves to test and train piloting ability under a variety of systematic and controlled conditions, VEs can be developed that create scenarios that may be similarly used to assess and rehabilitate human cognitive and functional processes. This work has the potential to improve our capacity to understand, measure, and treat the impairments typically found in clinical populations with CNS dysfunction as well as advance the scientific study of normal cognitive and functional/behavioral processes. The unique match between VR technology assets and the needs of various clinical application areas has been recognized by a number of authors (Rizzo, 1994; 1997; Pugnetti, 1995; Rose et al. 1997; Rizzo, Schultheis, Kerns & Mateer, 2003) and an encouraging body of research has emerged (Rizzo, Buckwalter and van der Zaag, 2002). What makes VR application development in this area so distinctively important is that it represents more than a simple linear extension of existing computer technology for human use. VR offers the potential to deliver systematic human testing and training simulation environments that allow for the precise control of complex, dynamic 3D stimulus presentations, within which sophisticated behavioral recording is possible. When combining these assets within the context of functionally relevant, ecologically valid VEs, a fundamental advancement emerges in how human cognition and functional behavior can be assessed and rehabilitated. This potential was recognized early on in a visionary article ("The Experience Society") by VR pioneer, Myron Kruegar (1993), in his prophetic statement that, "…Virtual Reality arrives at a moment when computer technology in general is moving from automating the paradigms of the past, to creating new ones for the future" (p. 163).

This submission focuses on our work developing a Head Mounted Display (HMD)-delivered VR scenario entitled: *The Virtual Classroom.* This scenario has been evolved from a research application into a commercial prototype. The commercial application is currently undergoing initial standardization testing to support its future marketing and distribution by The Psychological Corporation. The Psychological Corporation, a Harcourt Brace affiliate is the oldest and largest publisher of psychological and educational testing materials and this represents their first foray in the world of VR.

The Virtual Classroom

The Virtual Classroom is a HMD VR system for the assessment and possible rehabilitation of attention processes. Our efforts to target this cognitive process are supported by the widespread occurrence and relative significance of attention impairments seen in a variety of clinical conditions across the human lifespan. Most notably, attention difficulties are seen in persons with Attention Deficit Hyperactivity Disorders (ADHD), Acquired Brain Injury (ABI), and as a feature of various neurodegenerative disorders (i.e., Alzheimer's Disease, Vascular Dementia, etc.). VR technology appears to provide specific assets for addressing these impairments that are not available using existing methods. VEs delivered via HMDs are well suited for these types of applications as they serve to provide a controlled stimulus environment where attention challenges can be presented along with the precise delivery and control of "distracting" auditory and visual stimuli. This level of experimental control allows for the development of attention assessment/rehabilitation tasks that are more similar to what is found in the real world and could improve on the ecological validity of measurement and treatment in this area.

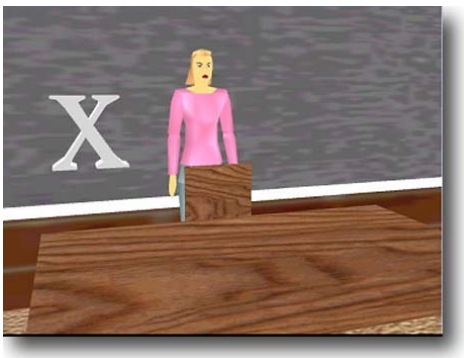
The initial research version of the Virtual Classroom scenario consisted of a standard rectangular classroom environment containing desks, a female teacher, a blackboard across the front wall, a side wall with a large window looking out onto a playground and street with moving vehicles, and on each end of the opposite wall, a pair of

doorways through which activity occurred. Within this scenario, children's attention performance is assessed while a series of typical classroom distracters (i.e., ambient classroom noise, activity occurring outside the window, etc.) are systematically controlled and manipulated within the virtual environment. The child sits at a virtual desk within the virtual classroom and on-task attention can be measured in terms of reaction time performance and error profiles on a variety of attention challenge tasks that are delivered visually using the blackboard or auditorily via the teacher's voice.

In the user-centered design phase, twenty non-diagnosed children (ages 6-12) were tested on basic selective and alternating attention tasks. We also solicited their feedback pertaining to aesthetics and usability of the VE and incorporated some of their comments into the iterative design-evaluate-redesign cycle. Overall results indicated little difficulty in adapting to use of the HMD, no self-reported occurrence of side effects determined by post-test interviews using the Simulator Sickness Questionnaire (Kennedy et al, 1993) and excellent performance on the stimulus tracking challenges. Following this phase, we conducted a clinical trial that compared eight physician-referred ADHD males (age 6-12) with ten non-diagnosed children. The attention testing involved a vigilance performance task delivered on the blackboard that required the participants to hit a response button whenever they saw the letter "X" preceded by the letter "A". Two 10-minute conditions were presented to participants: one without distraction and one with distractions (pure audio, pure visual and mixed A/V). VR performance was also compared with results from standard neuropsychological testing. As well, 6 Degree of Freedom tracking from the head arm and leg was used to produce motor metrics needed to analyze the motor hyperactivity component of this disorder. This first study revealed the following significant results:

- ADHD children made more Omission and Commission errors than non-diagnosed children across both conditions.
- ADHD children made more Omission errors (and a trend for lower commission errors) in the distracting condition compared to the non-distracting condition. This difference was not found with the non-diagnosed children.
- Motor movement in ADHD children (tracked from head, arm and leg) was higher on all metrics compared to non-diagnosed children across both conditions.
- Motor movement in ADHD children was higher in the distracting condition compared to the non-distracting. This was not found with the non-diagnosed children.
- A neural net algorithm trained to recognize a stereotypic leg movement on the first five participants in each group was able to accurately discriminate the remaining groups of subjects at 100%.

At the time of this study, these data suggested that the VR Classroom may have significant potential as an efficient, cost-effective and scalable tool for conducting attention performance measurement beyond what existed using traditional methodologies. More detailed information on the rationale, equipment, and methodology for this project can be found in Rizzo et al., (2001; 2002).



Images 1-4: Scenes from the original version of the Virtual Classroom developed at USC

Based on the early results of this work, The Psychological Corporation, in partnership with Digital Media Works Inc. funded the development of an advanced version of the *Virtual Classroom*. The resulting scenario borne of this work can be seen in the screenshots below.

Images 5-10: Scenes from the current version of the Virtual Classroom developed by Dr. Rizzo, Digital MediaWorks, and The Psychological Corporation

The Virtual Classroom was developed using a combination of proprietary applications and commercial software packages. All 3D models and assets were created using Discreet Max 4.x and 5.x. Textures and images were created using Adobe Photoshop 7.0 and Right Hemisphere's DeepPaint 2.0, along with several other image processing utilities.

The real time rendering engine itself is based on a modified version of Epic Games' next generation Unreal Warfare engine. All relative aspects of the participant's performance in the VE is tracked and recorded, such as the three relative axis of head motion, response time to stimuli, Field of View (FOV) during response hits, omission and commissions errors are all tracked and recorded in a database for post analysis and reporting.

Specific Assets for this application include:

1. Administration and Participant Management Interface
   - Provides tools to edit and manage examiner and examinee data
   - Allows viewing and printing of generated reports and participant scores
2. Run Time 3D graphics engine
   - Capable of high fidelity, near photo real rendering a realistic environment in real time.
   - Near Photo-real classroom virtual environment
   - High quality, animated students and teacher avatars
   - High quality, animated distraction objects
3. Run Time event management engine
   - Presentation and coordination of stimuli
   - Presentation and coordination distraction events
   - Synchronization and management of coordinated stimuli and distraction events

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