In Press: *The Proceedings of the 11th International Conference on Human Computer Interaction*

A Virtual Reality Scenario for All Seasons: The Virtual Classroom

Albert A. Rizzo[1, 2], Dean Klimchuk[2], Roman Mitura[2], Todd Bowerly[1], J. Galen Buckwalter[1], Kim Kerns[3], Katherine Randall[3], Rebecca Adams[4], Paul Finn[4], Ioannis Tarnanas[5], Cristian Sirbu[6],Thomas H. Ollendick[6] and Shih-Ching Yeh[1]

[1]University of Southern California Institute for Creative Technologies
13274 Fiji Way, Marina del Rey, CA. 90292

[2]Digital MediaWorks, 29 Allenby Road, Kanata, Ontario, Canada, K2K 2H3

[3]University of Victoria, Dept. of Psychology, Victoria, BC, Canada, V8W 3P5

[4]Saint Anselm College, Dept. of Psychology, 100 Saint Anselm Drive, Manchester, NH 03102

[5]Aristotle University of Thessalonica, Greece

[6]Virginia Polytechnic Institute, Dept. of Psychology, Blacksburg VA 24061-0436.

arizzo@usc.edu, dean@dmw.ca, roman@dmw.ca, buckwalt@usc.edu, kkerns@uvic.ca, krandall@uvic.ca, RAdams@Anselm.Edu, PaulFinn@Anselm.Edu, ioannist@auth.gr, csirbu@vt.edu, shihchiy@usc.edu

Abstract

Rather than relying on costly physical mock-ups of functional assessment and rehabilitation environments, VR offers the option to produce and distribute identical "standard" environments. Within such digital assessment and rehabilitation scenarios, normative data can be accumulated for performance comparisons needed for assessment, diagnosis and for training purposes. As well, in this manner, reusable archetypic virtual environments constructed for one purpose, could also be applied for clinical applications addressing other purposes. This has now been done with the Virtual Classroom scenario. While originally developed as a controlled stimulus environment in which attention processes could be systematically assessed in children while in the presence of varying levels of distraction, the system is now finding use for other clinical targets. Such applications that are being developed and tested using the Virtual Classroom for other purposes include: 1. Expansion of the range of attention assessment tests (i.e., a "Stroop" Interference testing system for all ages). 2. A wide field of view system to study eye tracking under distracting conditions with ADHD children using an Elumens *VisionStation*®. 3. Development of the Virtual Classroom as a tool for anxiety assessment and graduated exposure therapy for children with Social Anxiety Disorder. 4. An extension to the class to include a maze of halls leading out of the school for an earthquake safety training application with persons with developmental and learning disabilities.

1 Introduction

Virtual Reality (VR) has now emerged as a promising tool in many domains of therapy and rehabilitation (Glantz, Rizzo & Graap, 2003; Rizzo, Schultheis, Kerns & Mateer, 2004; Weiss & Jessel, 1998). The unique match between Virtual Reality (VR) technology assets and the needs of various clinical application areas has been recognized by a number of authors (Pugnetti, et al., 1995; Rizzo et al., 1994, 1998, 2002, 2004; Rose et al., 1996) and an encouraging body of research has emerged (Rizzo et al., 2002; Glantz, et al., 2003). Continuing advances in VR technology along with concomitant system cost reductions have supported the development of more usable, useful, and accessible VR systems that can uniquely target a wide range of physical, psychological, and cognitive clinical targets and research questions. What makes VR application development in the therapy and rehabilitation sciences 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 create systematic human testing, training and treatment environments that allow for the precise control of complex, immersive, dynamic 3D stimulus presentations, within which sophisticated interaction, behavioral tracking and performance recording is possible. Much like an aircraft simulator serves to test and train piloting ability, virtual environments (VEs) can be developed to present simulations that assess and rehabilitate human functional performance under a range of stimulus conditions that are not easily deliverable and controllable in the real world. When combining these assets within the context of functionally relevant, ecologically enhanced VEs, a fundamental advancement could emerge in how human functioning can be addressed in many clinical and research disciplines. 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).

Among the many advantages that VR offers clinical application development, one of its key assets is in the ability to create virtual simulations that could replace the process of building physical mock-ups of functional environments needed for human performance testing and training. This is a common method applied in the occupational sciences discipline to assess and rehabilitate functional abilities (Weiss & Jessel, 1998). Mock-ups of daily living environments (i.e., kitchens, bathrooms, etc.) and workspaces (i.e., offices, factory settings, etc.) are typically built, within which persons with motor and/or cognitive impairments are observed while their performance is evaluated. Aside from the real economic costs to physically build the environments and to provide human resources to conduct such evaluations, this approach is limited in the systematic control of "realworld" stimulus challenges and in its capacity to provide detailed performance data capture. As well, many functional environments in everyday life do not easily lend themselves to mock-ups, as is readily apparent in the domain of driving skill assessment and training. In this regard, "Behind-the-Wheel" driving assessments, considered to be the gold standard in this area, are often conducted in only the safest possible conditions (i.e, good weather, low traffic roadways, etc.), and actually provide a limited "window" into how driving performance would fare under more realistic (and often unpredictable) conditions. On the other end of the spectrum, traditional neuropsychological methods applied to disability assessment and rehabilitation commonly employ paper and pencil psychometric tests and training methods. Although these methods provide highly systematic control and delivery of performance challenges, they have also been criticized as limited in the area of *ecological* validity, that is, the degree of relevance or similarity that a test or training system has relative to the "real" world, and in its value for predicting or improving "everyday" functioning (Neisser, 1978). Adherents of this view challenge the usefulness of constrained analog tasks for addressing the complex integrated functioning that is required for successful performance in the real world.

A primary strength that VR offers assessment and rehabilitation is in the creation of simulated realistic environments in which performance can be tested and trained in systematic fashion. By designing VEs that not only "look like" the real world, but actually incorporate challenges that require real world functional behaviors, the ecological validity of assessment and rehabilitation methods could be enhanced. As well, within a VE, the experimental control required for rigorous scientific analysis and replication can still be maintained within simulated contexts that embody the complex challenges found in naturalistic settings. Thus, on a theoretical level, VR-derived results could have greater predictive validity and clinical relevance for the challenges that patients face in the real world. On a more pragmatic level, rather than relying on costly physical mock-ups of functional assessment and rehabilitation environments, VR offers the option to produce and distribute identical "standard" environments. Within such digital assessment and rehabilitation scenarios, normative data can be accumulated for performance comparisons needed for assessment, diagnosis and for training purposes. While the initial cost to produce a standard VE may be initially high, this financial outlay could be dissipated with cost sharing by professionals adopting the environment. As well, in this manner, reusable archetypic virtual environments constructed for one purpose, could also be applied for clinical applications addressing other purposes. This has now been done with the Virtual Classroom scenario. While originally developed as a controlled stimulus environment in which attention processes could be systematically assessed in children while in the presence of varying levels of distraction, the system is now finding use for other clinical targets. Such applications that are being developed and tested using the Virtual Classroom for other purposes include: 1. Expansion of the range of attention assessment tests (i.e., a "Stroop" Interference testing system for all ages). 2. A wide field of view system to study eye tracking under distracting conditions with ADHD children using an Elumens Dome. 3. Development of the Virtual Classroom as a tool for anxiety assessment and graduated exposure therapy for "speaking in front of a class of your peers" in children with social anxiety disorder. 4. An extension to the class to include a maze of halls leading out of the school for an earthquake safety training application with persons with Down's Syndrome and for kids with learning disabilities.

This paper will briefly describe the development of the VR Classroom, along with some of the initial findings on its use with children with ADHD. This will be followed by a discussion of the environment as it is being developed and applied for these new applications. The primary aim of this paper is to stimulate thinking on this cost-effective approach towards developing common archetypic environments that are reusable for multiple clinical targets. With current advances and continued cost reductions in both the hardware and software tools needed to use VR for clinical applications, a case will be made for the idea that significant benefits are looming on the horizon for the further integration of this form of simulation technology in the mental health and rehabilitation sciences!

2 The Virtual Classroom Project

2.1 Origins and Rationale

The original Virtual Classroom project began in 1999 as part of a basic research and commercial application program aimed at developing VR technology applications for the study, assessment, and rehabilitation of cognitive and functional processes. This work primarily focused on the development of systems that addressed the special 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, Virtual Environments (VEs) can be developed 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 Virtual Classroom is a HMD VR system for the assessment and possible rehabilitation of attention processes. This scenario has been evolved from a research application into a commercial prototype. The commercial application is currently undergoing initial standardization testing by the PsychCorp™ to support its future marketing and distribution. The PsychCorp™, a Harcourt Assessment affiliate is the oldest and largest publisher of psychological and educational psychometric testing materials and this represents their first foray in the world of VR. Our efforts to target this cognitive process were 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, and as a feature of various neurodegenerative disorders (i.e., Alzheimer's Disease, Stroke, etc.). VR technology appears to provide specific assets for addressing these impairments that are not available using existing methods. Head Mounted Displays (HMDs) that serve to occlude the distractions of the outside world are well suited for these types of cognitive assessment applications. In spite of their limitations, HMDs can provide a controlled stimulus environment where attention challenges can be presented along with the precise delivery and control of "distracting" auditory and visual stimuli within the virtual environment. 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 when delivered in the context of a relevant functional virtual environment, stand to improve on the ecological validity of measurement and treatment in this area.

Our first project with the Virtual Classroom focused on assessment of ADHD in children. The heterogeneous features of ADHD, a behavioral disorder marked by inattention, impulsivity, and/or hyperactivity, have made consensus regarding its diagnosis difficult. Furthermore, traditional methods for assessing ADHD in children have been questioned regarding issues of reliability and validity. Popular behavioral checklists have been criticized as biased and not a consistent predictor of ADHD, and correlations between concordant measures of ADHD, such as parent and teacher ratings of hyperactivity, have been repeatedly shown to be modest at best and frequently low or absent (Barkley, 1990; Colegrove et al., 1999). Due to the complexity of the disorder and the limitations of traditional assessment techniques, diagnostic information is required from multiple types of ADHD measures and a variety of sources in order for the diagnosis to be given (Barkley, 1990, APA, 1994; Greenhill, 1998). Thus, in the area of ADHD assessment where traditional diagnostic techniques have been plagued by subjectivities and inconsistencies, it was believed that an objective and reliable VR approach might add value over existing approaches and methods.

2.2 Structure of the Virtual Classroom and Research Methodology

The initial research version of the system was run on a standard Pentium 3 processor with the nVIDIA G2 graphics card. The HMD used in this study was the V8 model from Virtual Research. Tracking of the head, arm and leg used three 6DF magnetic "Flock of Birds" trackers from Ascension Technology Corp. In addition to driving the graphics display in the HMD, the tracking system also served to capture body movement metrics from the tracked locations. This provided concurrent data on the hyperactivity component that is a commonly observed feature of ADHD. The 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 (see Figure 1). Within this scenario, children's attention performance was assessed while a series of common classroom distracters (i.e., ambient classroom noise, activity occurring outside the window, etc.) were systematically controlled and manipulated within the virtual environment. The child sat at a virtual desk within the virtual classroom and on-task attention was measured in terms of reaction time performance and error profiles on a variety of attention challenge tasks that were delivered visually using the blackboard or auditorily via a virtual teacher's voice.

Early application of user-centered design methods is vital for the reasoned development of any VR application (Hix and Gabbard, 2002; Brown et al., 2001). User-centered methods generally require the involvement of the targeted user group in the early design and development phase of scenario development. This involves a series of tight, short heuristic and formative evaluation cycles conducted on basic components of the system. Consideration of user characteristics in this fashion is increasingly becoming standard practice in VR development (Hix et al, 2002). In the Virtual Classroom's user-centered design evaluation phase, twenty non-diagnosed children (ages 6-12) tried various evolving forms of the system over the first year of development and their performance was observed while trying out a variety of basic selective and alternating attention tasks. One such task involved having users

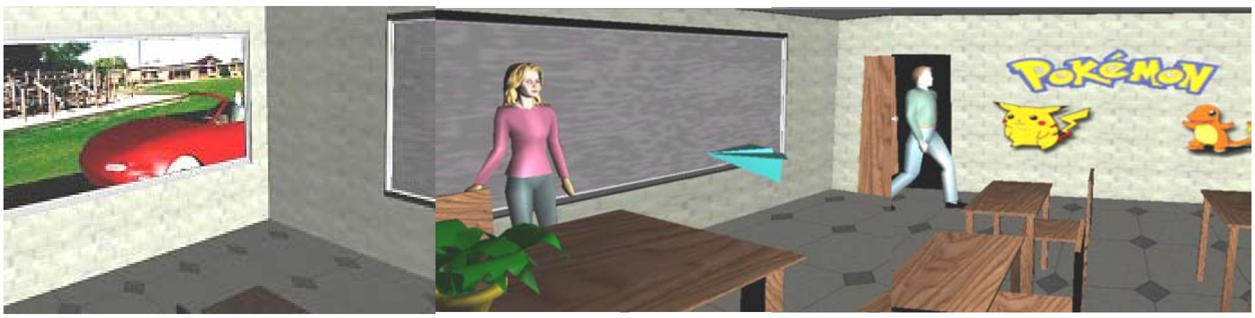

Figure 1. Scenes from the Initial Research Version of the Virtual Classroom

recite the letters that appeared on the blackboard, while naming the color of the paper airplane that passed by them at random intervals. We also solicited their feedback pertaining to aesthetics and usability of the VE and incorporated some of this feedback 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 as determined by post-test interviews using the Simulator Sickness Questionnaire (SSQ) (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 wireless mouse 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, six degree of freedom tracking from the head, arm and leg was used to produce movement metrics needed to analyze the motor hyperactivity component of this disorder.

2.3 Summary of Initial Virtual Classroom Results

- No significant side effects were observed in either group based on pre- and post-VR SSQ testing.
- ADHD children had *slower* correct hit reaction time compared with normal controls on the distraction condition (760ms vs. 610ms; $t\ (1,16) = -2.76$, $p < .03$).
- ADHD children had higher reaction time *variability* on correct hits compared with normal controls on both the no-distraction (SD= 220ms vs. 160ms; $t\ (1,16) = -2.22$, $p < .05$) and distraction conditions (SD= 250ms vs. 170ms; $t\ (1,16) = -2.52$, $p < .03$).
- ADHD children made more Omission errors (missed targets) compared with normal controls on both the no-distraction (14 vs. 4.4; $t\ (1,16) = -4.37$, $p < .01$) and distraction conditions (21 vs. 7.2; $t\ (1,16) = -4.15$, $p < .01$).
- ADHD children made more Commission errors (impulsive responding in the absence of a target) compared with normal controls on both the no-distraction (16 vs. 3.7; $t\ (1,16) = -3.15$, $p < .01$) and distraction conditions (12.1 vs. 4.2; $t\ (1,16) = -3.22$, $p < .01$)

● ADHD children made more Omission errors in the distraction condition compared to the non-distraction condition (21 vs. 14; t (1,14) = -3.50, p < .01). No such differences on Omission and Commission errors were found with the non-diagnosed children across no-distraction and distraction conditions.
● Exploratory analysis of motor movement in ADHD children (tracked from head, arm and leg) indicated higher activity levels on all metrics compared to non-diagnosed children across both conditions.
● Exploratory analysis of motor movement in ADHD children also indicated higher activity levels on all metrics in the distraction condition compared to the non-distraction condition. This difference was not found with the normal control children.
● An exploratory analysis using 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 subjects to groups at 100%.

These data suggested that the Virtual Classroom had good potential as an efficient, cost-effective and scalable tool for conducting attention performance measurement beyond what exists using traditional methodologies. The system allowed for controlled performance assessment within an ecologically valid environment and appeared to parse out significant effects due to the presence of distraction stimuli. Additionally, the capacity to integrate measures of movement via the tracking technology further added value to this form of assessment when compared to traditional analog tests and rating scales.

In this regard, a HMD appeared to be the optimal display format. Although one of the common criticisms of HMD technology concerns field of view (FOV) limitations, in this application the limited FOV fostered head movement to supplant eye movement as the primary method for scanning the Virtual Classroom. This type of "poor-man's" tracking of behavioral attention within the controlled stimulus environment obtained in the HMD allowed for ongoing documentation as to where the user is "looking" during test content stimulus delivery. For example, a child missing a target while directly looking at the blackboard is illustrating an attentional error that is fundamentally different from the occurrence of a missed target due to the child looking out the window at a distraction. The documentation provided by head tracking in a HMD can be used to produce metrics of % time on task during stimulus "hit" trials as well as allowing for a re-creation of a naturalistic behavioral performance record for later review. In the current research, ADHD children were found to miss targets due to looking away from the blackboard during 25% of the "hit" trials as opposed to normal subjects who were documented to be looking away at less than 1% of the time! This form of integrated cognitive/behavioral performance record of attention performance during delivery of systematic distraction is simply not obtainable using other methods. More detailed information on the rationale, methodology and long-term vision for this project can be found in Rizzo et al., (15-16).

2.4 Rationale and Technical Specifications for *The PsychCorp*™ Virtual Classroom Commercial Prototype

Based on the early results of this work, *The PsychCorp*™, in partnership with Digital MediaWorks Inc., funded the development of an advanced version of the *Virtual Classroom* using more sophisticated graphics and system architecture. The resulting scenario borne of this work can be seen in Figure 2. This version is now capable of delivering over 20 different types of distractions and allows for flexible building of distraction profiles in addition to defaults scenarios that will be supported with normative data for comparisons purposes across age and gender. Further, this functionally relevant "archetypical" environment was designed to be easily "retooled" for service to address other clinical targets and application areas.

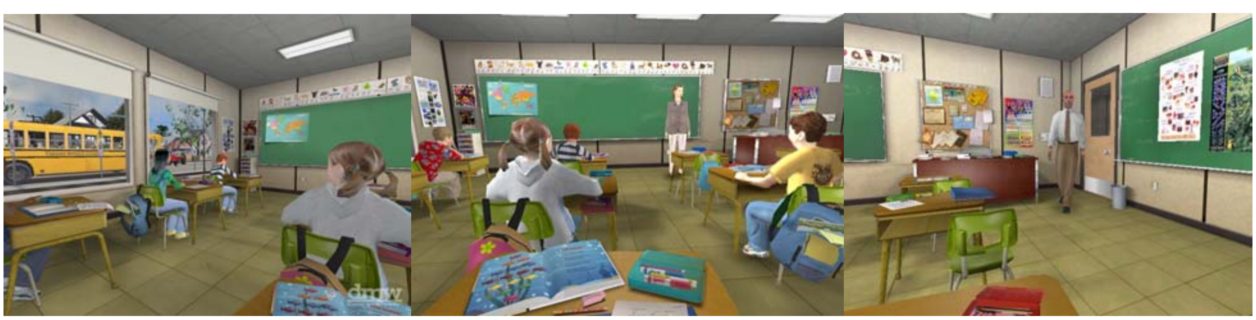

Figure 2. Scenes from the Commercial Prototype of the Virtual Classroom

One primary goal in this commercial development was to build a virtual environment that is as visually and functionally realistic as possible. Budget and resource limits meant achieving this goal by using mainstream COTS PC hardware and software. From a production standpoint the team focused on evolving content creation methods and customizing existing code rather than developing proprietary hardware solutions or unique rendering code. The advancement of commercial game engines, both in terms of technical capabilities and their own content creation tools appeared to be the obvious technical treatment. The decision to use a game engine as the foundation for the real time rendering component of the prototype was based on the belief that such software would provide the production team with a rapid prototyping tool capable of producing a quality end product without placing dramatic demands on available budget and resources. Even if building a proprietary rendering engine was within the team's technical capabilities, it was certainly not possible to build one with similar capabilities and required features within a reasonable time frame without investing budget and staff resources that greatly exceeded that of the entire project.

The rendering engine (Epic Games Unreal Engine 2.0) provided the team with the necessary raw rendering capabilities and mature production features. The Virtual Classroom was developed using a combination of proprietary applications and commercial software packages. Source material such as asset geometry and textures had to be translated into a format usable by the rendering engine, therefore it was critical that the existing production pipeline could accommodate the Unreal Engine. Fortunately, the Unreal engine had effective translation tools for many mainstream formats and a well developed set of proprietary tools for creating content in its native format. All 3D models and assets were created using Discreet's 3DS Max, while textures and images were created using Adobe Photoshop and various other image and graphics editing utilities. To achieve the level of desired realism, emphasis was placed on creating relatively high resolution geometric models and texture maps of the human avatars. These models were created in a separate modeling and animation package and then imported. The average geometric density of one student avatar was in the order of 10,000+ polygons, about 4-5 times greater than a typical game avatar. Displaying this level of detail fell easily within the capabilities of the Unreal engine, as it is capable of rendering scenes with relatively high geometric density - 60,000 to 100,000+ visible polygons. A Pentium 4 class processor and nVIDIA***TM*** G-Force2 video card provided more than adequate horsepower to render the classroom VE without any tearing or stuttering. Avatar textures were a blend of photographic images, original artwork, and manipulated digital imagery. The texture maps range in size from 512 x 512 pixels for face and head textures, down to 32x32 for repeating or distant surfaces. Textures were rendered in the native nVIDIA***TM*** DDS format with generated mip-maps. Since the participant's location in the classroom was fixed throughout the entire session, there was considerable latitude in terms of being able to use relatively low resolution texture maps on distant objects, without a loss in perceived realism. A collateral benefit to this approach was the ability to conserve texture space for higher resolution textures and greater geometric details on assets within close proximity to the participant's position.

Significant planning efforts went into the placement, proximity, and perceived impact of the various distraction sequences that occur throughout the testing procedure in the Virtual Classroom. Ambient sound was separate from the audio distractors and based on a looping audio track along with a queue of low level background sounds that were randomly timed and positioned within the environment. All other distractors were fixed in terms of their location, motion, and duration. Each time any distraction event was triggered it would always follow the same timing settings and motion paths. Maintaining consistent distracter presentation and accurate timing was paramount to the tracking and reporting system. As well, all relevant aspects of the subject's performance in the VE was tracked and recorded to a database for post analysis and reporting. Quantities included: the three relative axis of head motion, response time to target stimuli, gaze vector, and the number of omission and commission errors.

Using a game engine to prototype this particular VE application was certainly not without drawbacks. The Unreal Engine and its proprietary support features are tooled for a fast paced, dynamic, and visually intense experience. Many of the features and related code were simply not required and had to be stripped out for this application, while others required considerable modification or replacement to accommodate the classroom's event and measurement requirements. Above all, the team set out from the beginning to design and build an application that narrowed the gap between an assessment environment and the real world; to achieve a balance between the attractiveness of a game-like environment and the professionalism required in a cognitive assessment software application. The tools and resources available in the Unreal Engine helped move towards that objective.

Since the creation of latest version of the Virtual Classroom, multi-site clinical tests have been conducted in collaboration with the *The PsychCorp*™. Thus far, the results of this testing has replicated the initial findings from the original Virtual Classroom. Results from those studies will be presented at the conference along with an update on the expanded clinical trials that are currently being planned.

3 Development of Other Clinical Applications Using the Virtual Classroom

3.1 Expansion of Attention Process Assessment Tasks – The Virtual Stroop Test

Researchers at the University of Victoria have conducted tests with the Virtual Classroom investigating complex attention performance using a virtual version of the Stroop test. The Stroop effect is one of the most well established phenomena demonstrating interference control. The Stroop uses a color-word conflict design that requires the inhibition of a prepotent response to read color names when instructed to name conflicting ink colors. There have been a plethora of different Stroop paradigms, but this is the first Stroop task to be designed and used within a VR environment. The VR Classroom allows for a more controlled testing environment and reduces variability by controlling the participant's field of view and limiting the effects of unexpected visual and auditory distracters. While VR environments offer assets in terms of precise stimulus delivery and response recording, their utility for use with diagnostic tools, such as the Stroop test, has yet to be fully established. The purpose of this initial study was to assess the validity of a Stroop task given in a VR Classroom. It was hypothesized that the VR Stroop would produce "interference effects" similar to the classic paper and pencil format Stroop task (see Figure 3).

Eighty-one first year psychology students (25 males and 56 females), aged 17-33 (M = 19) from the University of Victoria participated. The participants wore a HMD to view the Virtual Classroom. An avatar teacher stands at the front of the classroom beside the chalkboard and states the instructions to the "class" before each task. The VR Stroop consists of two tasks. In the first task, colored boxes randomly appeared on the 'chalkboard', and in the second task, color words written in different colors of chalk appear randomly on the "chalkboard". In the second task, the stimuli are either 'congruent' (e.g., the word 'RED' appears in red chalk), or 'incongruent' (e.g. the word 'RED' appears in blue chalk). For each task, the teacher states a color as the stimulus appears on the board. The participant was instructed to click their mouse if the teacher's response correctly names the color of the chalk the stimulus appears in.

Mean reaction time (MRT) for each task was recorded in milliseconds. Repeated measures analysis revealed MRT to colored boxes was significantly faster than MRT to congruent word stimuli, and both were significantly faster than MRT to incongruent word stimuli. The results demonstrated that a Stroop test administered in a VR environment can produce 'interference effects' similar to a classic Stroop task. As expected, the colored boxes required no interference control, and thus reaction times to these stimuli were the fastest. Responses to the 'congruent' word stimuli were more cognitively demanding than responses to the colored boxes, and thus MRT was slower than that to boxes, but faster than that to incongruent word stimuli. The incongruent word stimuli were the most cognitively challenging, requiring interference control, and as expected, produced the longest MRT. The reaction times to the VR Stroop were slower than those typically found in response to a classic Stroop task. This is believed to result from the extent of cognitive processing necessary to complete the VR Stroop task. Specifically, participants must process the 'pictured' stimulus as well as a 'verbal' stimulus (teacher's response), and then determine if the teacher's response 'matches' their own before making a response. Research to investigate these effects in more detail is currently underway.

3.2 Wide Field of View System To Study Eye Tracking Under Distracting Conditions With ADHD Children Using An Elumens *VisionStation®*

In collaboration with the VR research group at St. Anselm College in New Hampshire, the Virtual Classroom has been configured to be displayed on an Elumens *VisionStation*® (see Figure 4). This research is evaluating the combination of the scenario and display system integrated with head movement and eye-tracking technology. The use of the Virtual Classroom with this display and response capture system provides a testbed for comparing performance in this non-HMD, wide field of view (FOV) system with findings from the original HMD application. If concordant results are found between these systems, such findings would lend support for the use of the lower cost HMD method in spite of its limited FOV. Alternatively, added performance information from the eye-tracking data acquired in the *VisionStation*® application, would be useful in its own right and could enhance our understanding of visual scanning behavior in persons with ADHD. Previous research has suggested that evaluation of eye-tracking may be useful in a virtual environment (Duchowski et. al., 2002), predicted it to be a good measure of sustained attention (Lavine, Sibert, Gokturk & Dickens, 2002), and found eye-tracking algorithms to be useful for correctly classifying adolescents with ADHD (Sneed, 1999).

Thirty-six boys (8-14 y/o) have participated in this research to date. Nineteen were diagnosed with ADHD, and sixteen served as non-diagnosed control subjects. The average age of each group was 10.2 and 10.4. Following informed consent and assent, a technician placed the *View Eye X Tracking System* helmet on the participant's head and the eye tracker was calibrated. The *SensoMotoric Instruments* system recorded participants' eye movement within the classroom environment through the use of an infrared light that is reflected back by all areas of the eye with the exception of the pupil. A sensor was also placed on each participants' non-dominant hand to record galvanic skin response. Participants were placed in front of the *VisionStation*® and familiarized with the classroom during a warm-up task. The Virtual Classroom vigilance task was then administered followed by the *Vigil*, a standard continuous performance attention task delivered on a flatscreen computer monitor. During testing, the subject's parents filled out a demographic questionnaire and *The Behavior Assessment System for Children* (BASC) parent report form (Kamphaus & Reynolds, 1998). The BASC is a behavioral rating scale consisting of four subscales: attention problems, hyperactivity, internalizing problems, and adaptive skills.

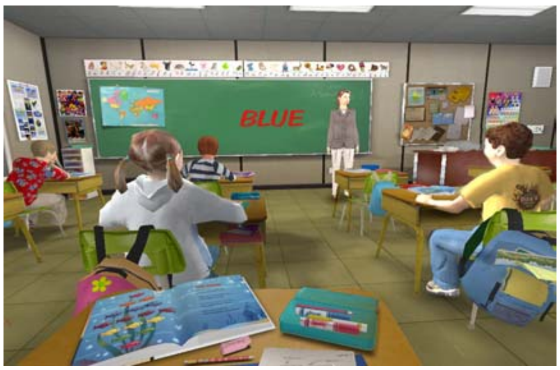

Figure 3. Scenes from the Stroop Test, an interference attention task

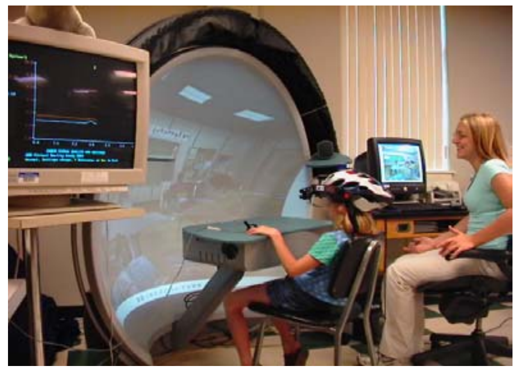

Figure 4. Virtual Classroom displayed on an Elumen's *VisionStation*® with eye and head tracking

For the ADHD group, a strong correlation was found between overall scores on the Virtual Classroom and the *Vigil,* as well as on the attention problems subscale of the BASC. However, the attention problems subscale of the BASC did not correlate with the standard *Vigil*. In addition, the ADHD group performed significantly poorer than controls on overall scores and had more omission errors in the Virtual Classroom (similar to results found in previous tests with the HMD system). Eye-tracking analysis revealed the ADHD group was more likely to look off task when the cue (the letter A) appeared on the board than the control group. Future research will investigate eye-movement data with free and cued recall of aspects of the Virtual Classroom and its relationship to galvanic skin response measures, teacher behavior ratings and classroom observation data.

3.2 The Virtual Classroom as a Tool for Anxiety Assessment and Exposure Therapy in Children and Adolescents with Social Anxiety Disorder (SAD)

Researchers from the Child Study Center at the Virginia Polytechnic Institute are now commencing tests of the Virtual Classroom with children and adolescents diagnosed with Social Anxiety Disorder (SAD). SAD is characterized by a marked and persistent fear of social or performance situations in which embarrassment or humiliation might occur. Children and adolescents with SAD report substantial distress across many social situations including (1) public performances (reading or reciting in front of others, performing in a play) and (2) ordinary social interactions (starting conversations, joining in on conversations, talking to adults, or talking on the telephone). Frequently, when exposed to possible scrutiny by others, youths with SAD fear they might do something or act in a way that will be embarrassing or humiliating. Although just the presence of others may elicit distress for some children, the general requirement to interact or perform in public creates substantial distress for the majority of children with this disorder (Ollendick, Hirshfeld-Becker, 2002). The classroom represents a context in which socially anxious children and adolescents typically experience their greatest struggles and consequences (Hofmann et al., 1999). Accordingly their reactions in a virtual classroom setting could provide data that is relevant for determining a diagnosis of social anxiety disorder, provide assessment data for determining outcomes following various cognitive-behavioral interventions and for the actual delivery of graduated exposure therapy.

To begin to address this challenge, the Virtual Classroom is now undergoing initial user trials for the assessment of SAD in children and adolescents. This adaptation of the Virtual Classroom environment, incorporating specific situations relevant for school related activities, represents a much needed link between laboratory and situational (in vivo) based assessment. Applied in this format, the user is positioned in the front of the virtual classroom and given a set of open-ended topics that they are asked to "speak about" to the class. Initial physiological and self-report data is being collected in order to determine anxiety and reactivity to the stimuli in the current classroom (see Figure 5). Contingent on these results, the scenario will be modified to include the capacity to control the number of virtual students in the classroom audience as well as their "behavior" in terms of activity and direct gaze levels. To date, no study has explored the assessment/treatment of SAD in children or adolescents using VR. The closest results are based on a case study investigating a young adult using a virtual classroom and auditorium for the treatment of test anxiety (North et al., 2004). The gradual exposure to six virtual situations produced a reduction in self-reported anxiety and an improvement in the subject's performance. These results are promising and invite further research involving the extension of the Virtual Classroom use as an assessment and therapeutic tool.

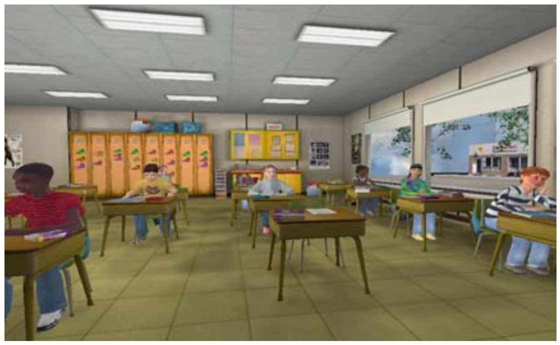

Figure 5. Virtual Classroom perspective from the front of the class as applied in initial user trials with children diagnosed with Social Anxiety Disorder

3.4 Earthquake Safety Training with Persons with Developmental and Learning disabilities.

Researchers at the Aristotle University of Thessalonica, Greece are about to begin test trials using an expanded version of the Virtual Classroom for earthquake safety training in children with developmental and learning disabilities. Children with these forms of disability often have cognitive impairments that limit the degree to which they can learn from traditional reading and lecture methods. Procedural learning "by doing" trials within a virtual environment may address this challenge. The design of this scenario included an expansion of the classroom to include a series of school hallways and part of an exterior schoolyard (see Figure 6). The classroom interior is populated with 12 students and a teacher, each capable of realistic emotive responses to an earthquake situation, such as showing fear, communicating distress to varying degrees and movement around the classroom. When an earthquake event is triggered, the virtual humans respond appropriately, items in the VE respond with some degree of physics, and the environment shakes along with the appropriate sound effects. Safety training will be provided via two basic modes of interaction – a guided "storytelling" mode and an interactive mode, where the participant controls his or her navigation/actions during and in the aftermath of a simulated earthquake. An interface is being developed to allow the researcher to observe and record the users actions as they navigate through the VE during training trials. These components are currently under construction, but initial test data is expected to be available at the time of the HCI conference.

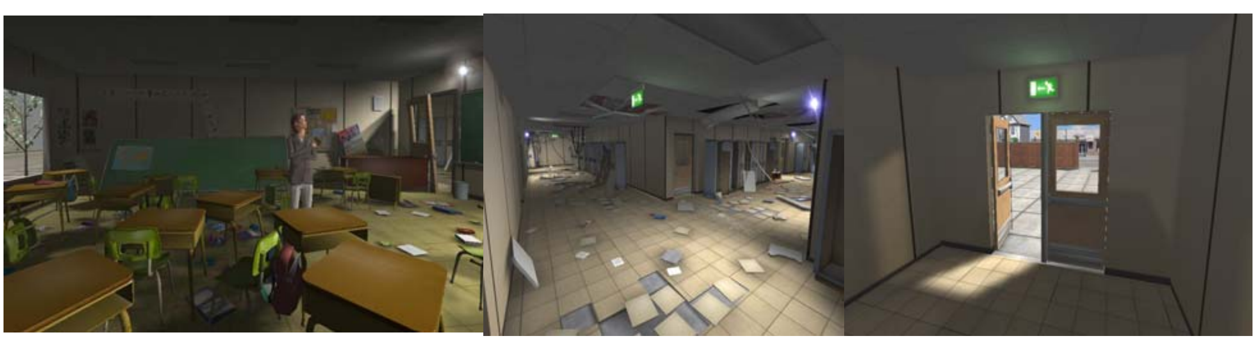

Figure 6. Virtual Classroom expansion to include hallways/outdoor schoolyard for earthquake safety training

References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). American Psychiatric Association: Washington, DC.

Barkley, R.A. (1990). *Attention deficit hyperactivity disorder: A handbook for diagnosis and treatment*. New York: Guilford Press.

Brown, D.J., Standen, P.J., Proctor, T. & Sterland, D. (2001). Advanced design methodologies for the production of virtual learning environments for use by people with learning disabilities. *Presence,* 10, *4,* 401-415.

Colegrove, R., Homayounjam, H., Williams, J., Hanken, J., & Horton, N.L. (1999). The problem of overreliance upon behavioral checklists in the diagnosis of ADHD. In *The 107th Annual Conference of the American Psychological Association*, Washington, D.C.

Duchowski, A., Medin, E., Cournia, N., Murphy, H., Gramopadhye, A., Nair, S., et al. (2002). 3-D eye movement analysis. *Behavior Research Methods, Instruments, and Computers*, 34 (4), 573-592.

Glantz, K., Rizzo, A.A. & Graap, K. (2003). Virtual Reality for Psychotherapy: Current Reality and Future Possibilities. *Psychotherapy: Theory, Research, Practice, Training,* 40, 1/2, 55–67.

Greenhill, L.L. (1998). Diagnosing Attention-Deficit/Hyperactivity Disorder in Children. *Journal of Clinical Psychiatry 59* (Suppl. 7), 31–41.

Hix, D. & Gabbard, J.L. (2002). Usability engineering of virtual environments. In *The Handbook of Virtual Environments,* (K Stanney, Ed.), Erlbaum Publishing: New York, pp. 681-700.

Hofmann, S. G., Albano, A. M., Heimberg, R. G., Tracey, S., Chorpita, B. F., & Barlow, D. H. (1999). Subtypes of social phobia in adolescents. *Depression and Anxiety*, 9, 15–18.

Kamphaus, R.W. & Reynolds, C.R.(1998). BASC monitor for ADHD manual and software guide. American Guidance Service, Inc.: Circle Pines, Minnesota.

Kennedy, R. S., Lane, N.E., Berbaum, K. S., & Lilienthal, M.G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *Inter. Jour. of Aviation Psy.* 3(3), 203-220.

Krueger, M.W. (1993). The experience society. *Presence, 2*, 162–168.

Lavine, R.A., Sibert, J.L., Gokturk, M. & Dickens, B. (2002). Eye-tracking measures and human performance in a vigilance task. *Aviation, Space, and Environmental Medicine*, 73 (4), 367-372.

Neisser, U. (1978). Memory: what are the important questions? In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical Aspects of Memory*. London: Academic Press. 3-24.

North M.M., North S.M., Crunk J. (2004) Virtual reality combats test anxiety: a case study report. *Studies in Health Technology and Informatics*, 98, 278-80.

Ollendick, T.H., Hirshfeld-Becker, D.R. (2002) The developmental and psychopathology of social anxiety disorder. *Biological Psychiatry*. Vol 51(1), 44-58.

Pugnetti, L., Mendozzi, L., Motta, A., Cattaneo, A., Barbieri, E., & Brancotti, S. (1995). Evaluation and retraining of adults' cognitive impairments: Which role for virtual reality technology? *Comp. in Bio.& Med 25*, 213-227.

Rizzo, A.A. (1994). Virtual Reality applications for the cognitive rehabilitation of persons with traumatic head injuries. In Murphy, H.J. (ed.), *Proceedings of the 2nd International Conference on Virtual Reality And Persons With Disabilities.* CSUN: Northridge.

Rizzo, A.A., Wiederhold, M. & Buckwalter, J.G. (1998). Basic Issues in the Use of Virtual Environments for Mental Health Applications. In Riva, G., Wiederhold, B., & Molinari, E. (Eds.) *Virtual Reality in Clinical Psychology and Neuroscience* IOS Press: Amsterdam. pp. 21-42.

Rizzo, A.A., Buckwalter, J.G. & van der Zaag, C. (2002). Virtual Environment Applications for Neuropsychological Assessment and Rehabilitation. In Stanney, K. (Ed.) *Handbook of Virtual Environments.* New York: L.A. Earlbaum. 1027-1064.

Rizzo, A.A., Bowerly, T**.,** Buckwalter, J.G., Schultheis, M.T., Matheis, R., Shahabi, C., Neumann, U. Kim, L., & Sharifzadeh, M. (2002). Virtual Environments for the Assessment of Attention and Memory Processes: The Virtual Classroom and Office. In Sharkey, P., Lanyi, C.S. & Standen, P. (Eds.), *Proceedings of the 4th ICDVRAT*. Reading, UK: University of Reading, 3-12.

Rizzo, A.A., Schultheis, M.T., Kerns, K. & and Mateer, C. (2004). Analysis of Assets for Virtual Reality Applications in Neuropsychology. *Neuropsychological Rehabilitation.* 14(1), 207-239.

Rose, F.D., Attree, E.A., & Johnson, D. A. (1996). Virtual reality: an assistive technology in neurological rehabilitation. *Curr Opin Neurol., 9*, 461-467.

Sneed, S. J. (1999). Eye response assessment of selective attention in adolescents with attention deficits (Doctorial Dissertation, University of Virginia, 1999). *Dissertation Abstracts International*, 2963, AAI9930088.

Stroop, J.R. (1935). Studies of interference in serial verbal reactions*. Jour. of Exper. Psy*., 18, 643-661.

Weiss, P. & Jessel, A.S. (1998). Virtual Reality Applications to Work. *Work, 11,* 277-293.