Diagnosing Attention Disorders in a Virtual Classroom

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The University of Southern California's Integrated Media Systems Center (http://imsc.usc.edu/) and Digital MediaWorks (www.dmw.ca/) have partnered to develop virtual reality 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 special needs of clinical populations with central nervous system dysfunctions such as brain injury, learning disabilities, or neurological disorders. By analogy, much as an aircraft simulator serves to test and train pilots under a variety of systematic and controlled conditions, researchers can develop virtual environments that help assess and rehabilitate human cognitive and functional processes.

The Virtual Classroom provides an efficient and scalable tool for conducting attention testing.

VIRTUAL CLASSROOM

The Virtual Classroom provides a head-mounted display VR system for the assessment and possible rehabilitation of attention disorders. Originally a research tool that used only basic software tools, we are evolving our initial research version into a commercial application.

Obviously, a commercial application would require a more advanced approach. To fill this need, we used Epic Games' Unreal Engine 2.0. This engine provided the development team with the raw rendering capabilities and mature production features required for integrating a combination of proprietary applications and commercial software packages.

The team had to translate source material such as asset geometry and textures into a format the rendering engine could use, which made it critical that the existing production pipeline could accommodate the Unreal Engine. Fortunately, the engine had effective translation tools for many mainstream formats and a well-developed set of proprietary tools for creating native-format content.

The commercial version of the Virtual Classroom is undergoing initial standardization testing by PsychCorp (http://marketplace.psychcorp.com), a Harcourt Assessment affiliate that publishes psychological and educational psychometric testing materials.

RESEARCH TOOL

The widespread occurrence and relative significance of attention impairments seen in a variety of clinical conditions support our efforts to target attention processes. The initial Virtual Classroom project focused on the assessment of attention processes in children who suffer from attention deficit hyperactivity disorder.

ADHD's heterogeneous features—inattention, impulsivity, and hyperactivity—have made consensus regarding its diagnosis difficult. Traditional analog and behavior checklist methods for assessing ADHD in children have raised reliability and validity questions. VR technology could provide specific assets for addressing attention impairments that are unavailable using existing methods.

Head-mounted displays that occlude the distractions of the outside world are well suited for these types of cognitive assessment applications. Despite some limitations, these displays 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.

Using these devices allows a high level of experimental control and supports the creation of attention assessment and rehabilitation tasks more like those found in the real world. This adds value over existing methodologies that have been plagued by subjectivities and inconsistencies.

In our study, we used a Virtual Research V8 head-mounted display. To track head, arm, and leg movements,

Figure 1. Virtual Classroom commercial model. This version features upgraded graphics courtesy of the Unreal Engine 2.0, developed initially for video games such as the first-person shooters Unreal and Unreal Tournament.

we used three position-and-orientation magnetic trackers from Ascension Technology. In addition to driving the graphics display in the head-mounted display, this tracking system also captured body movement metrics from the tracked locations. These metrics provided concurrent data on the hyperactivity component commonly observed in ADHD.

The research version of the Virtual Classroom scenario consisted of a rectangular classroom environment containing desks, a female teacher, a blackboard, and a large window looking out onto a playground and street with moving vehicles. On each end of the opposite wall, we positioned a pair of doorways through which activity occurred. Within this scenario, we assessed the child's attention performance while a series of common classroom distracters were systematically presented within the virtual environment.

CLINICAL TRIAL

Following a series of user-centered usability tests during the scenario's initial development, we conducted a clinical trial that compared eight physician-referred ADHD males, ages 8 through 12, with 10 nondiagnosed children. The attention testing involved a vigilance performance task delivered on the blackboard that required the children to hit a mouse button whenever they saw the letter X preceded by the letter A.

The children sat at a virtual desk within the classroom while we measured on-task attention in terms of reaction time and error profiles. We presented participants with two 10-minute conditions: one without distraction and one with pure audio, pure visual, and mixed audiovisual distractions. In addition, position-and-orientation tracking from the child's head, arms, and legs produced movement metrics needed to analyze hyperactivity.

This first study revealed the following:

- Neither group showed significant side effects, based on a pre- and post-VR simulator sickness questionnaire.
- ADHD subjects had slower correct hit reaction times compared with normal controls in the distraction condition.
- ADHD subjects made more omission errors and more commission errors compared with normal controls in both conditions.
- ADHD subjects made more omission errors in the distraction condition compared to the nondistraction condition. Normal controls showed no such differences.
- Exploratory analysis of motor movement in ADHD subjects—tracked from the head, arms, and legs—indicated higher activity levels on all metrics compared to nondiagnosed children across both conditions.

These results suggest that the Virtual Classroom can be an efficient and scalable tool for conducting attention testing beyond that available with traditional methodologies.

The system allowed systematic performance assessment within an ecologically valid environment and parsed out significant effects from the presence of distraction stimuli. Additionally, the capacity to integrate measures of movement via the tracking technology adds further value to this form of assessment compared to traditional analog tests and rating scales.

A common criticism of a head-mounted display technology concerns field-of-view limitations. However, in this application, this limitation fosters head movement to supplant eye movement as the primary method for scanning the virtual environment. This allowed ongoing documentation of where the user was looking during test content stimulus delivery.

For example, missing a target while directly looking at the blackboard shows an attentional error fundamentally different from missing a target because a distraction caused the child to look out the window. Other methods cannot provide an integrated cognitive and behavioral record of attention performance during delivery of systematic distractions.

COMMERCIAL APPLICATION

Based on our research results, PsychCorp partnered with Digital MediaWorks to fund the development of an advanced application using more sophisticated graphics and system architecture. This version, shown in Figure 1, can deliver more than 20 different distraction types. It also allows for flexible building of distraction profiles in addition to default scenarios that will be normed for comparisons across age and gender groups.

Building a virtual environment as visually and functionally realistic as possible is a primary goal. Budget and resource limits required achieving this goal by using mainstream commercially available PC hardware and software.

We based our decision to use the Unreal game engine as the foundation for the application's real-time rendering component on the belief that such software would provide the production team with a rapid prototyping tool capable of producing a quality product without placing dramatic demands on available budget and resources.

Technical specifications

We used Discreet's 3DS Max to create the Virtual Classroom's 3D models and assets; Adobe Photoshop and various other image and graphics editing utilities provided the tools for creating textures and bitmap images.

To achieve the desired realism level, we created relatively high-resolution geometric models and texture maps for the human avatars. Each student avatar had an average geometric density of more than 10,000 polygons—which made it four to five times denser than a typical game avatar. Displaying this level of detail fell easily within the capabilities of the Unreal engine, given that it can render scenes with a geometric density of from 60,000 to 100,000 visible polygons.

A Pentium 4 class processor and Nvidia G-Force2 video card provided the horsepower to render the classroom virtual environment without tearing or stuttering. Avatar textures incorporated a blend of photographic images, original artwork, and manipulated digital imagery. The texture maps ranged in size from 512×512 pixels for face and head textures down to 32×32 pixels for repeating or distant surfaces. We rendered the textures in the native Nvidia DDS format with generated MIP maps.

We used the Unreal game engine for the application's real-time rendering component.

Because the participant's location in the classroom remained fixed throughout the entire session, we had considerable latitude for using relatively low-resolution texture maps on distant objects without losing perceived realism. This approach also conserved space for higher-resolution textures and greater geometric details on assets within close proximity to the participant's position.

Distraction choreography

We sought to balance distractions in terms of type, placement relative to the user and blackboard target area, and duration. We separated ambient sound from the audio distracters and used a looping audio track along with a queue of low-level background sounds randomly timed and positioned within the environment.

We kept all other distracters fixed in location, motion, and duration. Maintaining consistent distracter presentation and accurate timing proved paramount to the tracking and reporting system's effectiveness. The system tracks and records all relevant aspects of the user's performance in the virtual environment, then stores this data for analysis and reporting. Parameters tracked include the three relative axes 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 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. Yet, instead of providing a labyrinth infested with hostile enemies, our environment gave users a high level of visual realism in a relatively passive setting that left them time to absorb details. The engine provided superb real-time rendering capabilities, a stable code base, and a mature and efficient asset integration pipeline.

Above all, the team's initial objectives were to design and build an application that narrowed the gap between an assessment environment and the real world while achieving a balance between the attractiveness of a gamelike environment and the professionalism required in a cognitive-assessment application. The tools and resources available in the Unreal Engine proved vital to achieving these objectives. ■

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