Virtual Environments for Human Performance Testing and Training

1. Research Team

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Industrial Partner(s):	Digital Media Works

2. Statement of Project Goals

The primary goals of this project are to design, develop, implement and evaluate psychometrically reliable and valid Integrated Media System (IMS) testing and training environments that target human cognitive and behavioral processes in normal and impaired populations. We have developed virtual environments (VEs) focusing on the study, assessment, and rehabilitation of attention, memory, visuospatial and executive cognitive processes [1-3].

We have used Projection-Based display technology to conduct a series of research field trials using ImmersaDesk-delivered scenarios that target assessment of visuospatial skills including visual field-specific reaction time, depth perception, 3D field dependency (virtual rod and frame test), static and dynamic manual target tracking in 3D space, and spatial rotation [1,2]. Our goals in this area involve iterative expansion of the range of component cognitive processes targeted and to apply these tools with a range of normal and clinical populations (brain-injury, stroke, learning disability, dementia) under varied perceptual (2D vs. 3D)/interaction (active vs. observational) conditions. We are also currently working on a similar system that would deliver this on a 3D flat screen system and into a stereo head mounted display (HMD).

We have also developed a series of immersive HMD virtual environments for the study, assessment, and rehabilitation of attention, memory and executive cognitive processes. One goal for the HMD VE involves continued iterative user-testing and refinement of these scenarios in order to maximize both the usability and usefulness of these types of testing/training integrated media systems. A goal that was sited in last year's report was to have these systems in use at major international research centers where data can be collected on a diverse range of user groups targeting specific research questions. Considerable progress has now been made on this goal, with IMSC systems in place at the following centers addressing a wide spectrum of related research questions:

- University of Victoria (Canada) – Rehabilitation of cognitive processes in learning disabled and traumatic brain injured (TBI) adult and child populations.
- Children's Hospital Los Angeles – Assessment of attention processes in children with ADHD and pediatric head injury; VR Distraction as an analgesic adjunct for children undergoing painful medical procedures.
- Kessler Medical Rehabilitation Research Center (New Jersey) – Assessment of memory and learning strategies in normal subjects and persons with TBI and Multiple Sclerosis.
- Western Toronto Hospital (Canada) – Attention and memory assessment in persons with sleep disorders.
- Sunnybrook Medical Center (Canada) – Functional Magnetic Resonance Imaging of brain function while performing prospective memory tasks within an ecologically valid test environment.
- Primary Children's Medical Center/University of Utah - Assessment of attention processes in children with mild pediatric head injury
- USC Alzheimer's Disease Research Center – Object memory assessment in healthy aged and Alzheimer's demented populations.
- St. Anslem's College Undergraduate VR Training Lab (New Hampshire) – Use of the virtual classroom and office for conducting undergraduate psychology experiments.
- Haifa University Dept. of Occupational Therapy (Israel) – Vocational assessment and training in virtual environments.
- Trinity College (Connecticut) – Prospective memory testing and training.

User Centered data that is collected in this range of settings, with this level of user and task diversity, continues to provide the knowledge required to drive the enabling technologies needed for system enhancement, better interface usability and support the development of accessible IMS technology needed to advance Universal Access and Information Society for All [4] concerns with populations having cognitive impairment and/or functional disabilities. Another previous goal of getting our applications into the mainstream of testing and training has also been accomplished by way of the IMSC spin-off company, Digital Media Works. This company now has a contract with the world's largest standardized testing company, the Harcourt-Brace owned "Psychological Corporation" to develop VR-based testing and training applications.

3. Project Role in Support of IMSC Strategic Plan

The design, development and evaluation of advanced integrated media systems (IMS) with attention to their usability and usefulness by humans is at the core of the IMSC mission. These projects have driven research on the underlying enabling technologies required to support efficient and effective system development that will also serve to advance the knowledge base available to other scientists addressing IMS development, implementation and evaluation. Enabling technology advancements in the areas of graphic rendering, avatar creation and immersidata capture and analysis have supported this effort. Future integration of IMSC advances in computer vision based tracking, haptics and immersive audio are expected to advance the usability and usefulness of the "next generation" of these systems.

4. Discussion of Methodology Used

A vital issue for the development of IMS is seen in an application's capacity to accommodate both the specific capabilities of the targeted user group and in its generalized usability by different user-groups having varying capabilities. Differences in areas of coordination, information processing, prior experience with similar tools, attitudes, motivation, and physical disability can be measured using a variety of metrics. These include questionnaires, psychometric testing, as well as behavioral testing and observation, using descriptive and experimental methods. Systematic assessment in these areas for specific target groups is conducted both at the start and throughout the application lifecycle.

Our first HMD system was designed to assess cognitive attention performance in normal children and children with Attention Deficit Hyperactivity Disorder (ADHD)[4] using a virtual classroom. The virtual environment (VE) consists of a classroom scenario that allows for ecologically valid diagnostic assessment of attention to target stimuli and motor reactivity while in the presence of systematically delivered distractions. The initial step in this process involved a thorough formal evaluation incorporating expert heuristic input from experts in the field of childhood attention processes and disorders. Guided by this initial input, the requirements for this system were specified and this information was analyzed from the standpoint of our own knowledge of the state of IMS technology. From this, a rough prototype of the Virtual Classroom system was created and user-centered design analysis with non-diagnosed children was commenced immediately. Over the span of a year and a half the system was evolved based on user testing results and feedback. This involved addressing issues of the usability of the HMD system, the response interface, testing for safe use and presence of side effects (cybersickness) and multiple stimulus tracking performance.

Following the user-centered design phase, a controlled clinical comparison evaluation trial was conducted. This involved testing of both ADHD diagnosed boys and normal controls (age 6-12) during three 10-minute test periods in the virtual classroom while distraction levels were systematically varied. All children were also tested on standard paper and pencil psychometric tests, behavioral rating scales and flat screen computer tests of attention. Attention performance was quantified by behavioral measures of reaction time and error rate. As well, six degree of freedom magnetic tracking of head, arm and leg was conducted to assess the hyperactivity component of this disorder. Questionnaire rating scales of cybersickness and presence were also administered to subjects. A successful collaboration with Cyrus Shahabi's Immersidata Lab has now lead to the development of data mining and quantification tools needed to conduct the complex analyses required to derive knowledge from this very complex and integrated set of performance metrics.

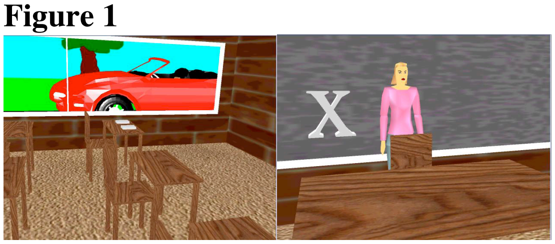
We have now begun the process of testing representative samples from different populations of users including children/adults/elderly, computer skilled/unskilled, and disabled/non-disabled in both our own lab studies and via our collaborative efforts at the sites listed in Section 2. This continues to iteratively evolve the usability and usefulness of these systems and provide new knowledge for both the design and development of IMS while addressing a useful human purpose by supporting refinements in diagnostic and rehabilitative efficacy. As well, the VR

Classroom is now being rebuilt using advance gaming graphics tools as part of Digital Media Works contract with The Psychological Corporation. We recently set up a demo booth at the International Neuropsychological Society Conference (Feb. 2003) and had over two hundred participants in this field try the prototype system and provide feedback via a nine-page questionnaire. This expert heuristic data is being analyzed currently and will serve to provide input that will assist in continuing to evolve this application for mainstream distribution. Similar data collection is planned with a much larger group of Educational and School Psychologists at the National Association of School Psychologists Convention in April 2003.

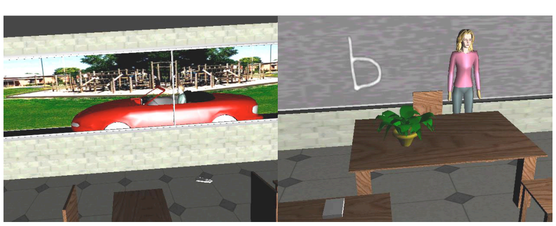
5. Short Description of Achievements in Previous Years

Leading up to the current year our achievements have centered on the informed construction of the system. The development of this system is a model for the application of user-centered design with a challenging user group, while at the same time addressing the concerns for creating a system that was usable and accessible to researchers and clinicians in the field. We have gone from running our system on a $200,000 SGI Onyx (far out of the price range of most potential users), to being able to deliver these scenarios on a commercially available laptop PC. Translation of code and graphics and audio rendering to these more accessible platforms was conducted concurrent with continued systematic user testing. An example of the advancement in the graphic realism that has been attained over the past 3 years can be seen in the Figure 1. We also have built and evolved a usable virtual "Office" environment from the basic design elements of the classroom and are involved with collaborative efforts that have lead to this scenario being tested with adult populations with multiple sclerosis and traumatic brain injury for similar purposes. This application is in place at one of the world's leading medical rehabilitation centers—the Kessler Medical Rehabilitation Research Center—and data from the first user study is now being analyzed. Additionally, a challenging process of having this research approved by the USC Institutional Review Board for the ethical treatment of research subjects was fully addressed with a template now in place to facilitate future approval of continued research in this area.

Figure 1



Virtual Classroom circa 1999



Virtual Classroom circa 2001

Virtual Classroom circa 2002

Virtual Classroom circa 2003

5a. Detail of Accomplishments During the Past Year

Since completing a very successful evaluation of the virtual classroom scenario we have commenced other trials with the scenario at a large number of international research centers. We are also collaborating with researchers using other systems that we have built (i.e., virtual office, virtual home) programmed to meet the multiple targets of assessment, rehabilitation and scientific investigation. We have also begun the initial development of the visuospatial scenarios that were cited in section 1, in a form that would be deliverable on a more accessible form, going from a $125,000 projection display (ImmersaDesk) to a PC-deliverable 3D flat screen and HMD application. Some of the key accomplishments include:

- Significant results continue to indicate that performance in the Virtual Classroom system successfully discriminates clinical groups.
- Discrimination metrics acquired in 20 minutes in our system were concordant with 2.5 hours of testing using traditional psychometric tools.
- Findings continue to support initial observations that VR Distraction testing produces results that discriminate groups in a way not possible with traditional methods.
- Hyperactive motor movement tracking and analysis using ImmersiData mining tools in collaboration with Cyrus Shahabi's lab further discriminated groups in a manner not possible with traditional methods [5].
- No critical incidents of negative side effects were found with the use of the system.
- Multiple user trials with an iteratively evolved VR Classroom with both female and male users have commenced.
- User testing has now begun on the Virtual Office that is targeting memory and learning strategy approaches in normal and cognitively impaired populations.

- Our system is now being further tested with collaborators at a wide range of research and clinical settings.
- The IMSC spin-off company, Digital Media Works now has a contract with the world's largest standardized testing company, the Harcourt-Brace owned "Psychological Corporation" to develop VR-based testing and training applications.

6. Other Relevant Work Being Conducted and How this Project is Different

While other labs are studying information processing in virtual IMS environments [6], our work is unique in our efforts to create a system that is usable and accessible to a larger number of researchers addressing research questions across a wide range of normal and clinical populations. As well, the systematic application of distraction and response capture/quantification/analysis at this scale has not been done by others with these clinical populations.

7. Plan for the Next Year

We plan to continue our system development in this area by:

- Further integration of Immersidata capture and analysis in collaboration with Cyrus Shahabi's lab.
- Begin exploratory testing on use of vision-based tracking methods to replace the existing magnetic system to target more effective interface design.
- Integrate Immersive Audio components into existing systems and assess added value.
- Integration of virtual human representations into our existing VEs that have believable appearance and action.
- Evolve our existing VR Office and Home environments based on current user testing data.
- Develop new environments using our existing development model.
- Continue developing collaborative efforts with outside institutions.
- Integrate findings on children's' performance in simulation environments in support of design and development of the IMSC 2020Classroom Project.

8. Expected Milestones and Deliverables

We have produced a scalable, usable, useful and accessible IMS that can be used as platforms for studying a range of generalized user-centered science questions while addressing "real-world" clinical issues for persons with disabilities and mental disorders. These projects will continue to drive IMSC technologies via the incorporation of facial animation/avatar construction, immersive audio, vision-based tracking, haptics and neural net immersidata mining procedures. One of the primary user-centered sciences questions in the development and potential usefulness of IMS, concerns the additive value of multi-sensory inputs (Audition, Haptics, and Olfaction) to what is presented using the visual modality. For example, we have collected baseline data with standard audio to compare with performance under 3D audio conditions. This research is designed to target 3D audio input effects on stimulus tracking, targeting, salience, mental encoding, and how this may impact human-computer interaction in virtual environments and more generally in IMS. Specifically, we will continue to investigate the use of 3D audio inputs for IMS applications that target human cognitive and perceptual testing/training, and for future applications designed to study the relationship between human information processing factors and system design. We will also address the degree to which 3D audio and haptics can facilitate or distract a person's capacity to obtain and process visual information presented in a VE. The results of this work could have impact on the relative weighting that is given to audio/haptic components in the design and development of IMSs in other areas. Additionally, by studying the effects of relative sensory weightings on the ecological validity of VEs, we will add to an understanding of what the "presence" requirements are for effective scenarios targeting different purposes [7].

9. Member Company Benefits

Advances in methods for creating and delivering IMS simulation tools applied to testing and training that has resulted in commercial product development via the Digital Media Works/Psychological Corporation effort.

10. References

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