Cognitive Performance Assessment in Mixed and Virtual Environment Systems

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ABSTRACT

The U.S. Army is currently interested in developing state-of-the-art training methods that leverage technology based on established and emerging immersive mixed and virtual environment systems employing both head mounted and spatially immersive display technologies. A primary motivation for utilizing mixed and virtual environment systems is that they create cost-effective simulations of relevant military challenges while training a variety of skills and processes. However, in a sometimes single-minded effort to directly advance training technology, the area of performance testing and assessment has often been overlooked. There are a number of compelling reasons to address the assessment component concurrently with efforts to build better training tools. It is nearly a given in modern psychology that, before one can begin to focus on training or enhancement of any behavior, one needs to be able to measure and understand the performance that needs to be trained. This requires assessment tools that have demonstrated reliability and validity for measuring criterion performance both pre and post training implementation. Without good assessment metrics, the measurement of training effectiveness is compromised, and as well, the ability to investigate and understand the components of effective performance that are needed to drive the evolution of a training system is not possible. To address this need, we have initiated development of a comprehensive, standardized, norm-based VR cognitive performance assessment test (VRCPAT) battery.

1.0 OVERVIEW

Cognitive performance testing is not a new area for the U.S. Army. The Army Alpha/Beta intelligence tests from WWI provide a historical illustration of the military's quest for standardized performance assessment to better guide selection, placement, and training decisions. Since that time, the military has routinely employed a wide range of performance assessment methods based on paper tests and subjective behavioral rating scales. As well, simulation technology has often been used to assess task specific performance primarily for ground vehicle and aircraft equipment operation. These efforts represent both extremes of the assessment spectrum—basic paper tests/rating scales and high level simulation technology—for the measurement of vastly different criterion performance (general declarative knowledge/implementation vs. specific highly proceduralized skills). The VRCPAT is envisioned to fill the middle ground between these two poles by creating a battery of VR-delivered performance tests that will serve to generate a normative database for performance evaluation and comparison. VRCPAT will leverage the assets that are available via the use of

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VR to assess cognitive performance that is required for success in the military, within the context of functionally relevant scenarios. Much like an aircraft simulator serves to test and train piloting ability under a range of controllable stimulus conditions, the long-term vision of the VRCPAT is to use VR simulation technology to create a battery of tests that assess the specific cognitive components that underlie all facets of successful military performance. Such cognitive components include attention, spatial ability, memory, executive functioning and a host of higher-level language and reasoning abilities.

The first phase of our VRCPAT effort focuses upon the development of a prospective memory module (PMM) delivered within the context of a VR middle eastern city scenario (Figures 1-2). A variant of this scenario has been used in a HMD based VR system designed for treating soldiers experiencing post traumatic stress disorder [1], (Figure 3). The scenario can also be used within the FlatWorld mixed reality system [2] which combines spatially immersive displays with theatrical staging techniques (Figure 4).

Prospective memory is widely regarded as the real-world memory ability needed to store and hold information in one's mind for later retrieval as required to successfully initiate and carry out a future functional task [3]. This is conjectured to be a core cognitive component ability that has general impact across all areas of military competency. Traditional tests of memory performance have primarily relied on word or object list learning. Typically, a person being tested with these tools is orally presented with a list of 10-16 contextually irrelevant words (or pictures of objects, etc.) and asked at a later time to recall them. While such tests may provide a crude measure of verbal memory storage that has some usefulness for diagnosing clinical populations on the low end of the performance spectrum, they have little value for predicting the dynamic cognitive performance ability required to carry out a mission in the types of complex environments that are characteristic of military operations. VR-based simulation technology approaches are considered to be the future alternative for devising cognitive assessment measures that will have better ecological/predictive validity for real-world performance.

Figure 1: Overhead View of Virtual City.

Figure 2: User View Inside Humvee.

Figure 3: VR PTSD System in Iraq.

Figure 4: FlatWorld Mixed Reality System.

2.0 ASSESSMENT PROCESS

The VRCPAT-PMM process consists of three primary phases described below followed by a debriefing.

2.1 Acquisition Phase

Users are presented with 10 pieces of language-based information to be learned, without any context for what they will need to do with this information. The information stimuli will be language based (i.e., a black Opal truck; the number 661; a dog; a man with white shoes; an abandoned mangled bicycle; bags of cement; a red door; a broken window; etc.). The acquisition phase will initially be standardized to five minutes. At the very end of the acquisition phase, users then will be asked to name the objects that they studied as an assessment of initial declarative recall memory.

2.2 VR Interface and Generic Task Training Phase

Following the acquisition phase, a five-minute "interface training" period will then occur in which users will become familiar with the controls of the game pad navigation interface and head mounted display within a non-relevant generic VR scenario. Users will navigate a barren city-like environment and will be required to visit five target zones that are marked with a blue numbered overhanging light that will signify the number identity of the zone where they will perform interface object location and selection actions similar to what will be required in the next phase.

2.3 Retrieval Phase

The users will remove the HMD and be given a top down map of the virtual environment that contains the five sequential well-marked target zones (blue light marked). Users will then be instructed that, when they next put on the HMD, a mission will begin. The user will then put on the HMD, and audio instructions will be presented regarding the task. Users will be told that they will need to go to each target zone in sequence (as they did in the previous phase), and at each zone, two of the items that they had memorized previously will be present somewhere in the environment from that vantage point. Upon finding the items, they should align the cross hairs with that object and press the response button to eliminate or "collect" them. Users will have one minute to spend within each target zone and scan for the relevant memorized target items. If they find the target items in less than the one-minute period, they can move on to the next zone, at which time they will have only one minute upon arrival to acquire those items. If the user does not find both objects in a target zone by the time that the one-minute period has elapsed, an alarm will sound and a voice will tell the user to move to the next zone and seek out the two objects located there.

2.4 Debriefing Phase

During this phase, users will be asked to recall the original list of stimuli and at which target zone they were found. Following this measure of pure recall, users could also be tested using cued recall and recognition assessment. Finally, an open-ended debriefing interview will be conducted to gather subjective information on user strategies that could be used both to further interpret the results and to evolve the design of the test.

The performance measures that will be derived from this test include: number of correct hits, false hits, time to successfully complete per target zone, time to complete overall, tracked total scanning behavior effectiveness, and efficiency of scanning. These metrics will be used to develop test norms by age and gender for evaluation and comparison, and these scores will be correlated with demographic and other performance tests measures administered.

3.0 SYSTEM TECHNOLOGY

The current VRCPAT PMM application is designed to run on a Pentium 4 notebook computer with 1 GB RAM and a 256 MB DirectX 9 compatible graphics card. The user navigates through the scenario using a simple USB game pad device while wearing an 800x600 resolution head mounted display (E-Magin Z800). In addition to HMD presentation, the VRCPAT PMM can be configured for delivery on a standard LCD monitor or using large, spatially immersive displays in either monoscopic or stereoscopic modes. The application is built upon ICT's FlatWorld Simulation Control Architecture (FSCA) [4]. The FSCA facilitates a network-centric system of client displays driven by a single controller application. The controller application broadcasts user-triggered or scripted-event data to the display clients. The real-time 3D scenes are presented using Emergent's Gamebryo graphics engine. Art content is created, edited and exported to the engine using Autodesk's Maya software.

4.0 REFERENCES

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Overview

- Motivation
- Virtual Reality and Psychology
- Test Structure
- Development Plan
- Software, Hardware Platform
- Target Systems

Motivation: Bridging a Gap

- **Assessment methods:** Two extremes
- **Technological low end:** Paper and pencil tests, WWI Alpha/Beta Intelligence tests
  - Often used for selection and placement, test general cognitive skills
- **Technological high end:** Vehicle simulators, test highly proceduralized skills over a range of conditions
- Two approaches for measuring different criteria represent extremes of the assessment spectrums
- How can you bridge this gap and update the technology used to test cognitive components such as *attention*, *spatial ability, memory, executive functioning and a host of higher-level language and reasoning abilities?*
  - **Why?** These components are all critical for successful military performance

Solution: VRCPAT Battery

- Create a Virtual Reality Cognitive Performance Assessment Test (VRCPAT) Battery
- VRCPAT uses immersive simulation environments to deliver tests that assess the specific cognitive components that underlie all facets of successful military performance.
- VRCPAT can deliver the test under a range of controllable stimulus conditions within relevant simulated military operational contexts

VR and Psychology

- VR mental rotation tests
- ADHD assessment
- VR pain distraction
- Vietnam PTSD (Georgia Tech, Atlanta VA, Emory 1997)
- Iraq PTSD (ONR 2004-Present)

VR and Psychology

- Virtual Vietnam (1997)

VR and Psychology

- Sparse graphics
- Rich sound environment compensated, spawned audio-vision correlation study (1999)
- Clinically validated by VA, Emory study

VR and Psychology

- Virtual Iraq (USC, ONR sponsored 2004-Present)

VR and Psychology

- Sent to Iraq for feedback from combat stress team
- Uses game rendering engine (Emergent Gamebryo)
- Art assets from Full Spectrum Warrior and other game based sim projects

VRCPAT: First Step

- Prospective Memory Module (PMM)

- Why memory?

  - Prospective memory is widely regarded as the real-world memory ability needed to store and hold information in one's mind for later retrieval as required to successfully initiate and carry out a future functional task.

  - Conjectured to be a core cognitive component ability that has general impact across all areas of military competency.

  - Example: Presence patrols

Prospective Memory Module

- Traditional tests of memory performance have primarily relied on word or object list learning.
- Variant of the scenario is being used in Virtual Iraq
- PMM is delivered within the context of a virtual middle eastern city

Prospective Memory Module

- Four Phases
  - Acquisition
  - Interface Training
  - Retrieval
  - Debriefing

Acquisition Phase

- Users are presented with 10 pieces of language-based information to be learned, without any context for what they will need to do with this information
  - A black Opal truck; the number 661; a dog; a man with white shoes; an abandoned mangled bicycle; bags of cement. etc.
- At the very end of the acquisition phase, users then will be asked to name the objects that they studied as an assessment of initial declarative recall memory.

Interface Training

- Users become familiar with the controls of the game pad navigation interface and head mounted display within a non-relevant generic VR scenario.

- Users will navigate a barren city-like environment to visit five target zones that are marked with a blue numbered overhanging light

- Number signifies the number identity of the zone where they will perform interface object location and selection actions similar to what will be required in the next phase.

Retrieval Phase

- Users told to go to each target zone in sequence as they did in the previous phase
- Two objects memorized previously will be in each zone
- Upon finding items, users align them in a reticle and collect by pressing a button
- Users have one minute in each zone to collect the items. Two of the items that they had memorized previously will be present somewhere in the environment from that vantage point.
- Users can go to the next zone after collecting the items
- If one minute passes without collecting the objects, they are forced to go to the next zone

Debriefing phase

- **Pure recall test**: Users will be asked to recall the original list of stimuli and at which target zone they were found.
  - Next users can be tested using cued recall
- **Open-ended debriefing interview:** Gather subjective information on user strategies that could be used both to further interpret the results and to evolve the design of the test.

Performance Measures

- The performance measures that will be derived from this test include:
  - Number of correct hits
  - False hits
  - Time to successfully complete per target zone
  - Time to complete overall
  - Tracked total scanning behavior

- Metrics will be used to develop test norms by age and gender for evaluation and comparison

- Scores will be correlated with demographic and other performance tests measures administered

Development Plan

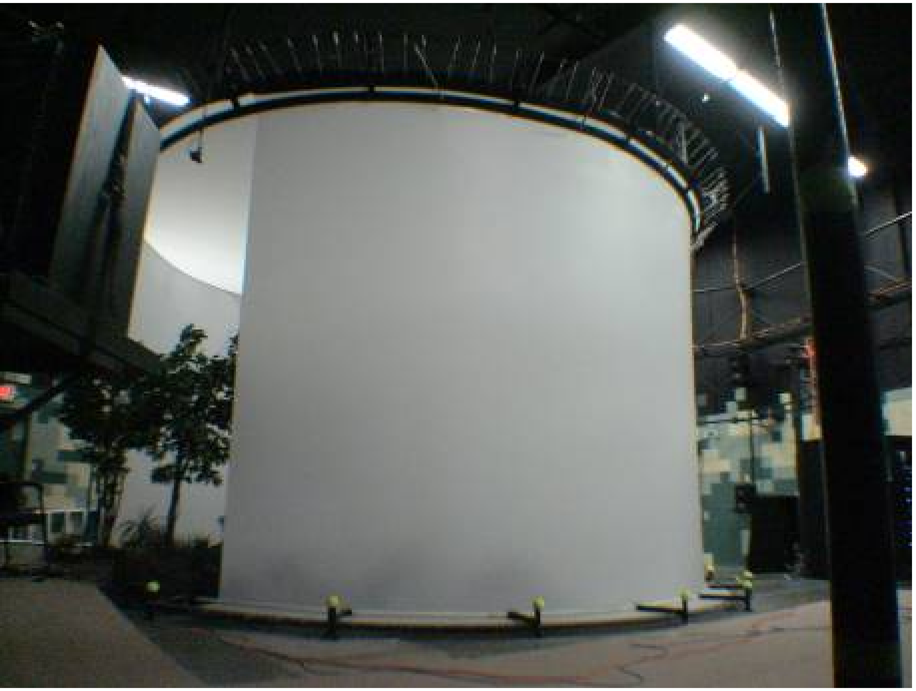
- Software complete late July/early August 2006
- Test trials in August 2006
- Additional cognitive assessment modules developed in 2007
- Conduct tests in mixed reality systems spanning the virtuality continuum

Hardware, Software Platform

- **Rendering:** Emergent's Gamebryo Rendering Library
- **MR System Support:** Video see-through AR using AR-TAG, multi-channel projection displays, passive/active stereo, auto stereoscopic displays, HMD's
- **Tracking:** E-magin, Inertiacube2, Polhemus, 3rd-tech
- **Audio:** Tracked OpenAL 3D audio, headphones, dozens of channels
- **Multisensory FX:** Audio tactile effects, DMX protocol for fog, strobe, heat

Spatially Immersive Displays

Spatially Immersive Displays



FlatWorld : Wide Area Mixed Reality

FlatWorld Urban Terrain Module

- FlatWorld based Urban Terrain Module: Ft. Sill Oklahoma

  - MR System: Temperature controlled, user tracked, handheld virtual binos

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