Instrumented Multitask Assessment System (IMAS)

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This work presents an immersive virtual reality system that we have built to accurately quantify servicemember (SM) performance in simulated field exercises of varying complexities. Although military virtual reality simulators have been presented by other investigators, their practical value has been limited because they either require a room-scale installation (Collins et al., 2015) or are not truly immersive (Scherer et al., 2017). We have developed the Instrumented Multitask Assessment System (IMAS) which is simultaneously fully immersive and small enough to be deployable in any clinic or training facility. We have instrumented the IMAS with biometric sensors for continuous data collection during simulations. These signals can be used as real-time biofeedback, enabling the simulated tasks to vary in difficulty until target values such as stress levels or heart rates are achieved. Finally, the IMAS can administer cognitive or psychometric tests in-simulation, thus allowing mental acuity to be quantified under field-related duress. The system is easily reconfigurable and extensible, both with respect to simulated environments and biosensors.

Design Overview: The subject walks or runs in an omnidirectional treadmill (Omni, Virtuix, Austin, TX) while wearing an immersive virtual reality headset (VIVE Pro, HTC Corp., Taiwan). The VR environment is customizable and programmable in Unity (San Francisco, CA). A typical application requires the subject to follow a variable-speed foot patrol leader while responding to environmental stressors and distractors. The 360° Omni Virtuix treadmill allows the subject to move for an arbitrary duration in any direction, which means the foot patrol can make turns and move around obstacles for added realism. In our proof-of-concept application, the speed of the patrol leader is determined through closed loop biofeedback in order to achieve a target heart rate. Biomedical recordings including brain (EEG), heart (ECG), and movement kinematics are synchronized and stored for post-hoc analysis. The system is managed by a central host computer that renders the virtual reality and collects and synchronizes data from the various sensors. The system is extensible through a standardized interface that can easily accommodate new peripherals and sensors.

Peripheral data streams can be collected through a variety of interfaces, including Bluetooth, USB, and TCP. Time synchronization is enforced by the host computer, which compels the sensors to provide one sample per graphical frame of the VR system. The VR system nominally operates at 90 frames per second, although the value may fluctuate according to the instantaneous demands on the host computer processor. Our observed frame rate is 90.3±5.3 frames/sec. Owing to the graphically intensive nature of the system, the host machine is an Alienware Aurora R7(J) with a GeForce GTX 1080 GPU, 16 GB of RAM and an Intel i7 8700k 6-core CPU. The entire system, including treadmill, has a footprint of just 2m x 2m.

Biometric Sensors: Although the system is extensible, our pilot application includes the following sensors: Both of the subjects' feet are fitted with an Omni (Virtuix) inertial measurement unit (IMU) that captures linear acceleration in three dimensions, roll, pitch, yaw, and orientation in three-space. Shimmer (Dublin, Ireland) IMU sensors capture acceleration and roll, pitch, and yaw data from both hands, and from the subject's upper back and head. The Omni treadmill's built-in sensors also provide orientation angle, which shows the direction the subject is facing, as well as the orientation and direction where the hands are pointing. Electrocardiogram data is measured with a Bitalino (Plux Wireless Biosignals, Arruda dos Vinhos, Portugal) data acquisition board, with a 3-lead ECG extension collecting a single lead heart signal. Beats per minute are computed in real time using this data. Electroencephalogram signals are collected using a 20-channel EEG recorder (Grass Model 2, NeuroNatus, Middleton, WI) connected to a National Instruments (Austin, TX) analog-to-digital converter (PCI 6224). Finally, a Shimmer GSR sensor records galvanic skin response.

Cognitive Tests: Inspired by the paradigm described in (Scherer et al., 2017), the IMAS can present tests of cognition and/or acuity directly in the simulation environment, which can be performed under well-calibrated levels of subject duress. Tests include dual and multi-task paradigms in which combinations of verbal cognitive, arithmetic cognitive, working and short-term memory loading, or motor sub-tasks are performed. In our proof-of-concept case, we designed a target-selection test in which the subject has to differentiate between desirable and non-desirable targets and fire a simulated weapon accordingly. Test results are scorable in terms of reaction times, accuracy of aim, and accuracy of target selection. The test can be made arbitrarily complicated by varying the sizes, number, and movements of the targets, as well as their visual contrast with respect to the background scenery.

Results: The result of each trial is a plaintext data file in CSV format containing all aggregated data. Each line shows the time at which the reading occurred, and the time elapsed from the previous reading (for calculating sampling period variability). All sensor readings, calculations and event descriptions are paired with their respective time stamps. Data collected during multiple subject tests confirm that the VR frame rates are stable and that sensor data can be regularly logged for tens of thousands of samples consecutively without dropped packets.

Background: Virtual reality has emerged as a strong medium for performance research in the military, despite limitations such as its generally large footprint. Scherer used virtual reality to allow subjects to perform a simulated foot patrol in front of a fixed screen while identifying and counting IEDs (Scherer et al., 2017). Others have used head-mounted VR to implement military-specific divided attention tasks in an open space that allowed the subject to move freely (Robitaille et al., 2017). Case studies showing successful application of VR for TBI rehabilitation in SMs have also been published (Gottshall et al., 2012; Rábago & Wilken, 2011). VR has applications for stress management training in the military (Pallavicini et al., 2016) as well as with medical skills training in SMs (Siu et al., 2016).

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