WIRELESS MONITORING OF HUMAN NEUROLOGICAL AND PHYSIOLOGICAL ACTIVITY AND MOVEMENT IN IMMERSIVE 3D VIRTUAL REALITY ENVIRONMENTS

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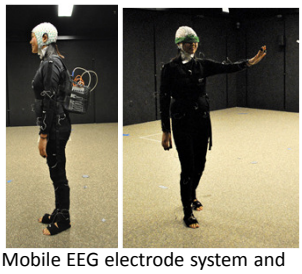
Wearable wireless-enabled sensors provide new opportunities to monitor a variety of electrical signals revolutionizing scientific investigations of human behavior and physiology and facilitating the creation of novel diagnostic, preventative or treatment methods in more realistic environments. We have designed and are currently implementing non-invasive means to measure brain activity and other electrophysiological signals associated with cognitive and motor function in immersive 3D audiovisual and motion-enabled virtual reality environments; employing up to 64 channels of brainwave EEG, 8 electrode EOG systems, and multi-electrode dry-contact and non-contact EMG/ECG arrays.

DEVICES

One of the utilized light EEG systems using multi dry electrodes, allowing for quick setup without application of conductive gel and minimally-encumbered collection of EEG signals during mobile experiments.

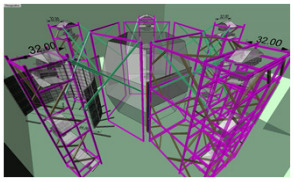


Mobile EEG electrode system and IR position tracking body suit in use in the MOBI Lab for experiments on movement control.

Portable EOG systems, new 12-channel (left) and 8-channel prototype (right) are used for gaze tracking in virtual environments, monitoring changes in attention and fixation.

Core experimental technologies:
- Lightweight, wireless (Bluetooth) connected systems
- Multiuse electrodes
- Various dry electrode designs
- Incorporated motion tracking systems
- StarCAVE joystick and wand

ENVIRONMENTS



Development is done in the StarCAVE (above), a projected 3D virtual environment, providing a fully immersive, 360º VR experience; incorporating head tracking and control devices to allow more realistic interaction and free movement within the virtual environment. Images show a protein structure displayed in the StarCAVE and a diagram of the UCSD StarCAVE setup.

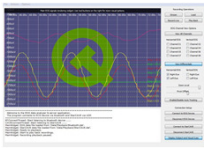
Other environments used for development:
- SoniCAVE – an environment for spatially realistic virtual sound development
- MOBI Lab – motion observation lab for experiments involving free movement & mobile EEG

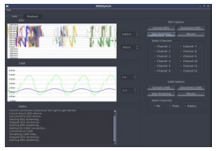
Development is also done in the NexCAVE, a more portable 3D VR environment providing partial immersion via linked 3D screens and integrated 3D sound.

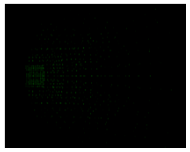
DATA COLLECTION & ANALYSIS

Technological Benefits of Experimental System :
- Untethered, natural movements and responses to stimuli
- Realistic presentation of multimodal stimuli
- Immediate experimental feedback and responsive stimuli modulation

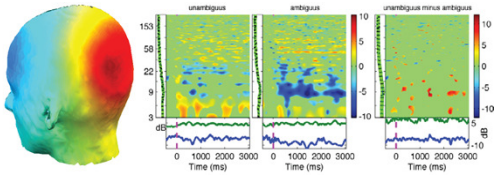
Involved analytical methods:
- Fast Fourier transform
- Moving average
- Independent component analysis
- Principle component analysis







Data from various sources (wireless EEG/EOG devices, Cave positional data, and experimental stimuli) are synchronized with signals displayed in real time for immediate feedback. Windows based program (left), new Linux program (middle), screenshot of calibration grid used in EOG tracking (right).

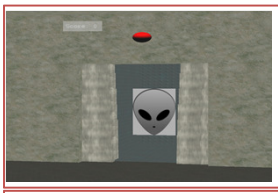


256 channel electrode arrays are used to reveal different EEG frequency responses in unambiguous spaces compared to ambiguous virtual reality spaces devoid of wayfinding cues.

Cognitive Processes of Interest:
- Visual spatial skill
- Spatial navigation
- Attention
- Memory
- Executive functions
- Cognitive decline

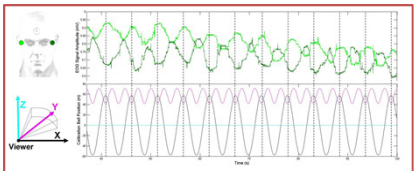
A screenshot of a virtual model of the a new building (Nanoengineering at UCSD). Realistically rendered models of buildings allow for wayfinding and attention experiments preconstruction.

APPLICATIONS



Screenshot of 3D virtual game under development for the purpose of testing executive function and reappraisal in neurotypical and autistic children, by presenting expected and unexpected auditory and visual stimuli.

Other Planned Applications:
- long-term monitoring of outcomes of interventions
- Testing treatment strategies and protocols
- Assaying complex clinical procedures in realistic settings
- Training and education of medical personnel



Correlated EOG data showing EOG signals captured while tracking a virtual object. Position curves of the object are shown (second curves) during a calibration run. This EOG data is able to be used for eye tracking in 3D and for use in attention experiments.

Acknowledgements & Funding

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Publications

[1] L. Zhang, J. Gossmann, C. Stevenson, M. Chi, G. Cauwenberghs, K. Gramann, J. Schulze, P. Otto, T.-P. Jung, R. Peterson, E. Edelstein and E.R. Macagno. "Spatial Cognition and Architectural Design in 4D Immersive Virtual Reality: Testing Cognition with a Novel Audiovisual CAVE-CAD Tool. " On-line contribution to Spatial Cognition in Architectural Design (SCAD-11) Conference, New York, NY, November 16-19, 2011.

[2] Zhang, L., Chi, Y.M., Edelstein, E.A., Schulze, J., Gramann, K., Velasquez, A., Cauwenberghs, G., and Macagno, E. (2010) Wireless Physiological Monitoring and Ocular Tracking: 3D Calibration in a Fully-Immersive Virtual Health Care Environment. Proc. IEEE Engineering in Medicine and Biology Conf. (EMBC),

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