HPR*net*
Human Performance Research *network*

Enhancing Human performance using Virtual Reality, Wearable Computing, Cognitive Neuroscience and Mental Training

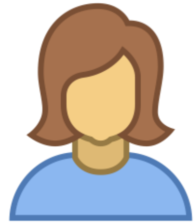
Research Aim: To implement VR/AR environments, neurocognitive methodologies and mental training for individualized approaches to screening, monitoring and training for performance in complex and challenging situations.

University of South Australia

THE AUSTRALIAN ARMY

DST GROUP | Science and Technology for Safeguarding Australia

Project Team



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Cognitive Psychology
DSTG

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Computer Science
HCI, AR, VR

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AR, VR, Wearables

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Cognitive Neuroscience

Dr. Maarten Immink
Health Sciences
Motor control learning

Prof. Mathias Schlesewsky
Psychology and Social Work
Cognitive Neuroscience

Plus 3 PhD students, 1 Research Engineer, 1 Intern, 1 visiting PostDoc

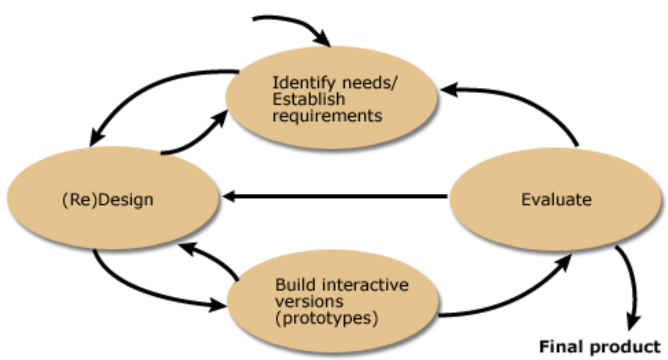
Project Design

1 *Hypotheses*

1. Cognitive aware AR + VR training will significantly improve training
2. Training in cognitive VR + AR will produce improved real world performance
3. Lightweight cognitive sensing can produce results similar to full EEG systems

2 *Experimental methodology*

Interaction Design approach



3 *Deliverables*

- Quality journal papers
- Prototype demonstrations
- Software frameworks
- Experimental results
- Field testable systems

4 *Timelines*

2017 – tech. fundamentals, background
2018 – pilot physiology study in AR/VR
– VR + EEG comparative study
2019 – study in realistic warfighter env.
– team training study
2020 – handheld system development
– Field deployment study

Using cognitive tools to design optimal AR/VR training

1. Create AR/VR training environment - Simulate real world task
2. Monitor cognitive load while training - EEG, physiological cues
3. Tune environment to maximize learning, minimize cognitive load
4. Measure transfer of training to real world

Progress, Challenges and Opportunities

Progress to date

- May report delivered – background literature review
- Milestone 1A – review of cognitive training – underway
- Technical report on AR and EEG - underway
- Technology demonstrators developed (VR, AR + EEG)
- Access to army training activities 2017 provided
- Recruitment underway (1 PhD secured)

Challenges

- Student recruitment – PhD admission timing
- Understanding training domain
- Deciding on types of training tasks

Opportunities

- DSTG collaboration (cognitive gym)
- Collaboration with HPRnet partners

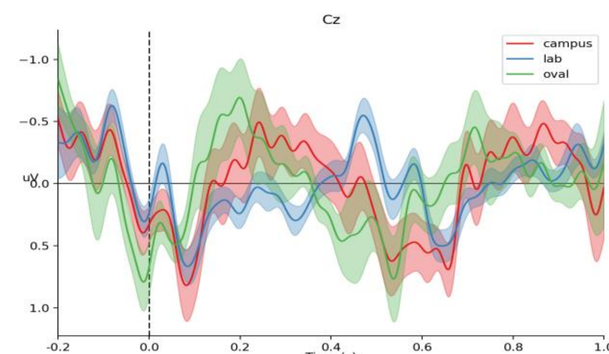
Preliminary Studies

1: Measuring Heart Rate Variability in Virtual Reality

- Explore best ways to measure HRV
- Shown HRV affected by VR environment
- Capture HRV plus other physiology cues

2: Measuring Pupil Dilation in Virtual Reality

- explored how to reliably measure pupil dilation in VR HMD
- develop calibration and measurement tool
- exploring correlation with stress/cognitive load



3: Piloting of EEG Measures in Mobile Environments

- contrast lab EEGs measures to EEG when moving outdoors
- feasible to measure EEG under mobile recording conditions

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Measuring Heart Rate Variability in VR

Aims

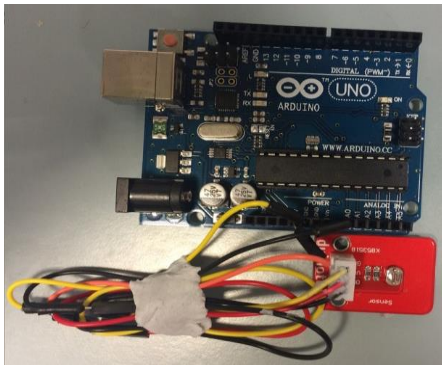
- To reliably measure heart rate variability in VR
- To test HRV as a measure for emotional response to VR

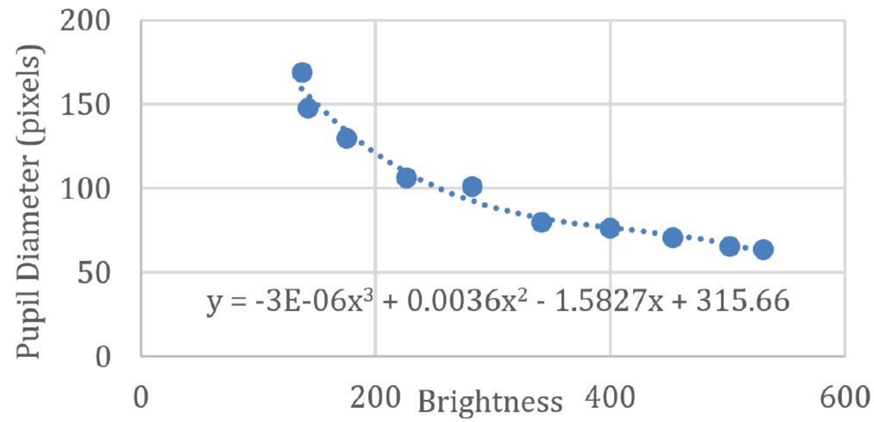
Results

- Testing with wrist and chest straps, also GSR
- Found different HRV in different types of VR environments
- Shown that HR cues can also affect HRV
- Challenging to separate HRV from activity and arousal

Condition	*Baseline*	*Butterfly*	*Zombie*
HR	86.7 (15.1)	99 (15.6)	112.4 (11.7)
NoHR	79.1 (3.4)	104.5 (7.2)	106.1 (13.8)
Overall	83.1 (11.6)	101.6 (12.3)	109.4 (12.6)

Measuring Pupil Dilation in Virtual Reality



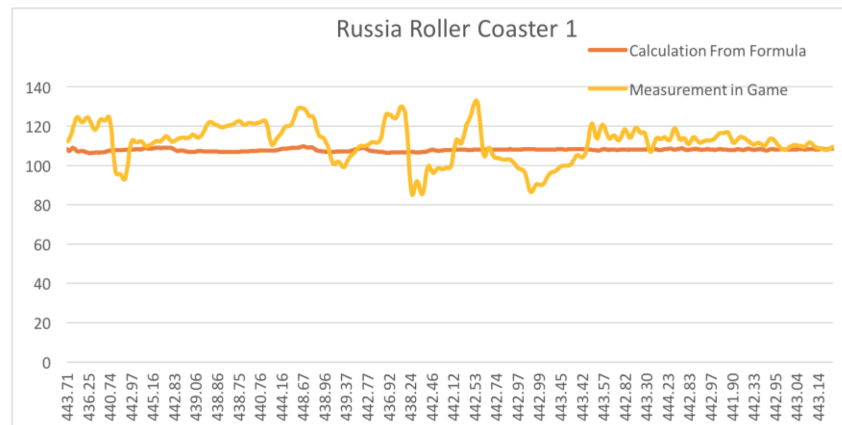


Aims

- Pupil dilation in response to cognitive load/emotion
- Calculate method of reliably measuring dilation in VR

Results

- Developed hardware and software for calibration
- Measuring individual baseline response to fixed lighting
- Testing in five different emotional VR experiences
- Found pupil dilation to be reliable measure of arousal



Proof-of-concept: EEG in mobile environments

Aims

- to contrast EEG signal quality in a laboratory vs. mobile outdoor setting under conditions of high or low attentional demand
- to develop data acquisition and analysis protocols for obtaining high-quality measures of individual neural activity during cognitive processing in mobile environments

Experimental protocol

- auditory oddball paradigm (sequence of frequent, ”standard” tones interspersed with infrequent, “deviant” tones
- active (count the deviants) and passive (ignore the tones) tasks, known to elicit mismatch negativity (MMN) and P300 event-related potentials, respectively
- three testing scenarios: in lab, walking around oval, navigating around campus (mix of outdoors and indoors) using a map

Experiment uses a Brain Products LiveAmp, a state-of-the-art ultra-mobile (wireless) EEG recording system; movement compensation via internal accelerometer

Ongoing Work

1: Cognitive Load in VR

- using discrimination tasks
- cognitive gym like task
- Training discrimination ability

2: Using EEG to Measure Cognitive Load in AR/VR

- combining EEG + HoloLens/HTC Vive
- develop AR/VR system that adapts based on cognitive load
- conduct simple discrimination studies

3: *Systematic review of cognitive training*

- milestone 1A, due November 15th 2017

4: *Measuring brain activity in VR and AR*

- milestones 1B, 1C, due May 2018

Technology Demonstrations

1/ Virtual Reality and Cognitive Load
- discrimination task in immersive VR
- select target using head pointing
- increasing number of targets

2/ EEG + HoloLens Integration
- using EEG to measure cognitive load
- discrimination task with AR display
- use cognitive load to change difficulty

Related Research Outputs

Chen, H., Dey, A., Billinghurst, M., Lindeman, R. (2017). Exploring the Design Space for Multi-Sensory Heart Rate Feedback in Immersive Virtual Reality. In *Proceedings of the 29th Australian Conference on Computer-Human Interaction*. ACM.

Chen, H., Dey, A., Billinghurst, M. (2017). Exploring Pupil Dilation in Emotional Virtual Reality Environments. In *Proc. of the 27th International Conference on Artificial Reality and Telexistence (ICAT 2017)*.

Baumeister, J., Ssin, S. Y., ElSayed, N. A., Dorrian, J., Webb, D. P., Walsh, J. A., ... & Thomas, B. H. (2017). Cognitive Cost of Using Augmented Reality Displays. *IEEE Transactions on Visualization and Computer Graphics*, *23*(11), 2378-2388.

Dey, A., Piumsomboon, T., Lee, Y., & Billinghurst, M. (2017). Effects of Sharing Physiological States of Players in a Collaborative Virtual Reality Gameplay. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (pp. 4045-4056). ACM.