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.
**Project Team**

Dr. Diane Pomeroy  
Cognitive Psychology  
DSTG

Prof. Mark Billinghurst  
Computer Science  
HCI, AR, VR

Prof. Bruce Thomas  
Computer Science  
AR, VR, Wearables

Prof. Javaan Chahl  
Engineering  
UAV, Sensor Systems

Prof. Ina Bornkessel-Schlesewsky  
Psychology and Social Work  
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
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

<table>
<thead>
<tr>
<th>Condition</th>
<th>Baseline</th>
<th>Butterfly</th>
<th>Zombie</th>
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</thead>
<tbody>
<tr>
<td>HR</td>
<td>86.7 (15.1)</td>
<td>99 (15.6)</td>
<td>112.4 (11.7)</td>
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<tr>
<td>NoHR</td>
<td>79.1 (3.4)</td>
<td>104.5 (7.2)</td>
<td>106.1 (13.8)</td>
</tr>
<tr>
<td>Overall</td>
<td>83.1 (11.6)</td>
<td>101.6 (12.3)</td>
<td>109.4 (12.6)</td>
</tr>
</tbody>
</table>
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


