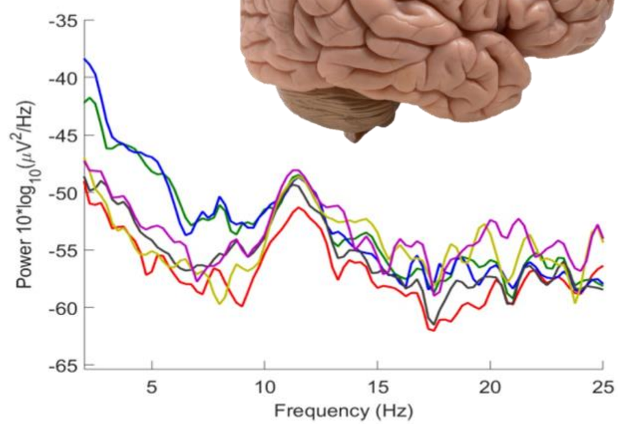
HPR*net*
Human Performance Research
network

Enhancing Human Performance Using Virtual Reality, Wearable Computing, Cognitive Neuroscience and Mental Training

US Army



Research Aim: To implement VR/AR environments, neurocognitive methodologies and cognitive training for individualised 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

Australian Government
Department of Defence
Science and Technology

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Project Team

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Skill Acquisition, Human Performance

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Psychology
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Plus 3 PhD students, 1 Research Engineer, 1 Intern, 1 visiting Postdoc

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 markers
3. Training environment to maximize learning, minimize cognitive load
4. Cognitive training for enhancement of learning and performance

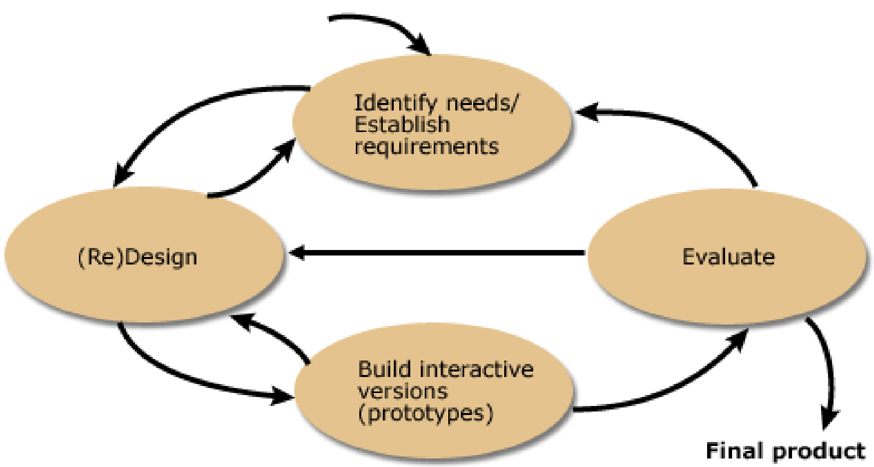
Project Design

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.
– cognitive training study
2020 – handheld system development
– field deployment study

Progress, Insights, Challenges, Opportunities

Progress to date

- Review of cognitive training evidence delivered (Milestone 1A)
- EEG + VR training system developed (Milestones 1B, 1C)
- Completed user study with EEG + VR system (Milestone 1B)
- Developed EEG + AR system (Milestone 2A)
- Developed cognitive training interventions for evaluation (Milestone 3E)

Insights

- Integration of AR/VR and EEG in training is possible
- EEG reliably assesses real-time cognitive load in military related VR training tasks
- VR training systems can be adapted based on traditional cognitive load measures
- Evidence supports transfer benefits from cognitive training

Challenges

- PhD student recruitment
- Complexity of training domain
- Difficulty of working with EEG + VR
- Time demands for EEG user studies
- Heterogeneity in cognitive training approaches

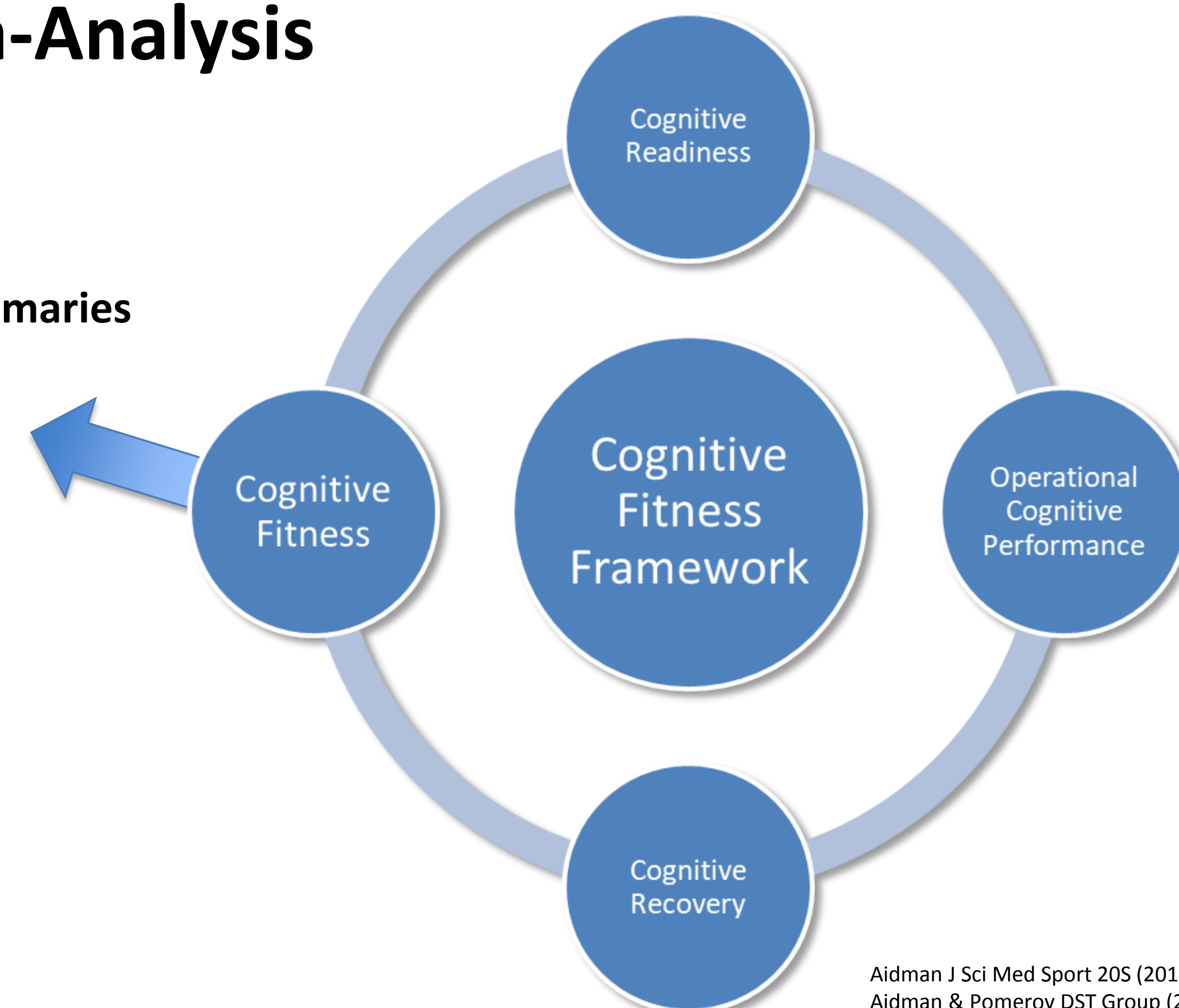
Opportunities

- DSTG collaboration (cognitive gym)
- Collaboration with HPRnet partners
- Using EEG/VR/AR platform for multiple studies
- Innovative cognitive training platforms

Transfer benefits from cognitive training: Systematic Review & Meta-Analysis

Trainable Cognitive Primaries

- Self-awareness
- Attention skills
- Task Switching
- Impulse control
- Co-action



Aidman J Sci Med Sport 20S (2017) S50–S52
Aidman & Pomeroy DST Group (2017)

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Transfer benefits from cognitive training: Systematic Review & Meta-Analysis

Cognitive training intervention, Healthy adults 18-60, Transfer (untrained task) performance assessment

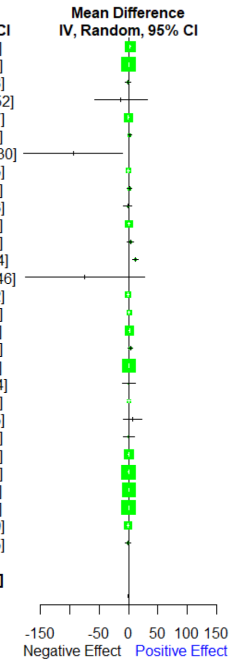
28 Studies Included

Modalities of Cognitive Training:

- Working Memory
- Video Game
- Meditation

	Experimental			Control				Mean Difference
Study	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Baniqued et al. 2014	23.23	1.6970	43	20.15	1.5740	44	7.2%	3.08 [2.40; 3.77]
Bartlett et al. 2009	0.13	0.3500	57	0.02	0.3700	56	13.2%	0.11 [-0.02; 0.24]
Bettis 2017	48.78	8.1900	31	49.58	10.4600	31	0.3%	-0.80 [-5.48; 3.88]
Bhayee et al. 2016	457.00	65.4000	13	469.70	51.4000	13	0.0%	-12.70 [-57.92; 32.52]
Boot et al. 2008	9.15	1.9000	20	9.32	1.3800	19	4.5%	-0.17 [-1.21; 0.87]
Buelow et al. 2015	29.90	11.5600	114	28.10	12.0900	114	0.7%	1.80 [-1.27; 4.87]
Chiappe et al 2013	279.24	157.2300	27	373.41	154.2900	26	0.0%	-94.17 [-178.04; -10.30]
Colom et al. 2012	12.20	2.6000	10	12.30	2.3000	10	1.4%	-0.10 [-2.25; 2.05]
Colom et al. 2013	37.23	6.2300	28	35.46	8.2600	28	0.5%	1.77 [-2.06; 5.60]
Couture et al. 1999	35.02	12.4900	22	36.02	10.9000	22	0.1%	-1.00 [-7.93; 5.93]
Daugherty et al. 2017	17.00	6.4200	212	16.25	7.4900	212	3.2%	0.75 [-0.58; 2.08]
Dunning & Holmes. 2014	19.28	9.4800	22	15.75	8.5300	23	0.3%	3.53 [-1.75; 8.81]
Foster et al. 2017	50.15	13.2900	58	38.42	14.2500	58	0.3%	11.73 [6.72; 16.74]
Green et al. 2012	443.00	100.0000	8	517.00	119.5800	10	0.0%	-74.00 [-175.46; 27.46]
Hardy et al. 2015	101.36	29.5500	2667	102.68	30.7600	2048	2.0%	-1.32 [-3.06; 0.42]
Harrison et al. 2013	10.76	2.5280	21	9.82	3.7620	17	1.5%	0.94 [-1.15; 3.03]
Jaeggi et al. 2014	13.36	2.2200	52	11.81	2.2700	47	5.5%	1.55 [0.66; 2.44]
Jausovic et al. 2012	32.40	5.6500	14	29.20	6.3400	15	0.4%	3.20 [-1.16; 7.56]
Lilienthal et al. 2013	3.81	0.4700	13	3.27	0.9000	26	10.1%	0.54 [0.11; 0.97]
Lindeløv et al. 2016	29.40	11.9000	9	29.20	11.1000	8	0.1%	0.20 [-10.74; 11.14]
Lussier et al. 2012	24.10	3.9000	13	23.10	2.8000	10	0.9%	1.00 [-1.74; 3.74]
Menezes & Bizarro. 2015	113.70	21.7000	14	107.00	25.2000	19	0.0%	6.70 [-9.35; 22.75]
Naranjo & Schmidt 2012	40.20	11.2000	10	40.20	10.8100	11	0.1%	0.00 [-9.43; 9.43]
Schmiedek et al. 2010	25.60	2.7000	101	25.20	2.5000	44	5.4%	0.40 [-0.51; 1.31]
Shahar & Meiran. 2015	0.72	0.2000	15	0.67	0.1200	16	13.3%	0.05 [-0.07; 0.17]
Shute et al. 2015	0.16	0.6200	42	-0.18	0.6700	34	11.7%	0.34 [0.05; 0.63]
von Bastian & Eschen 2016	0.59	0.2000	34	0.48	0.1800	32	13.4%	0.11 [0.02; 0.20]
von Bastian & Eschen 2016	8.00	2.7400	34	8.81	2.2100	32	3.7%	-0.81 [-2.01; 0.39]
Zeidan et al. 2010	22.00	7.9000	24	23.00	8.3600	25	0.3%	-1.00 [-5.55; 3.55]
Total (95% CI)			**3728**			**3050**	**100.0%**	**0.51 [0.24; 0.78]**
Prediction interval								**[-0.31; 1.32]**

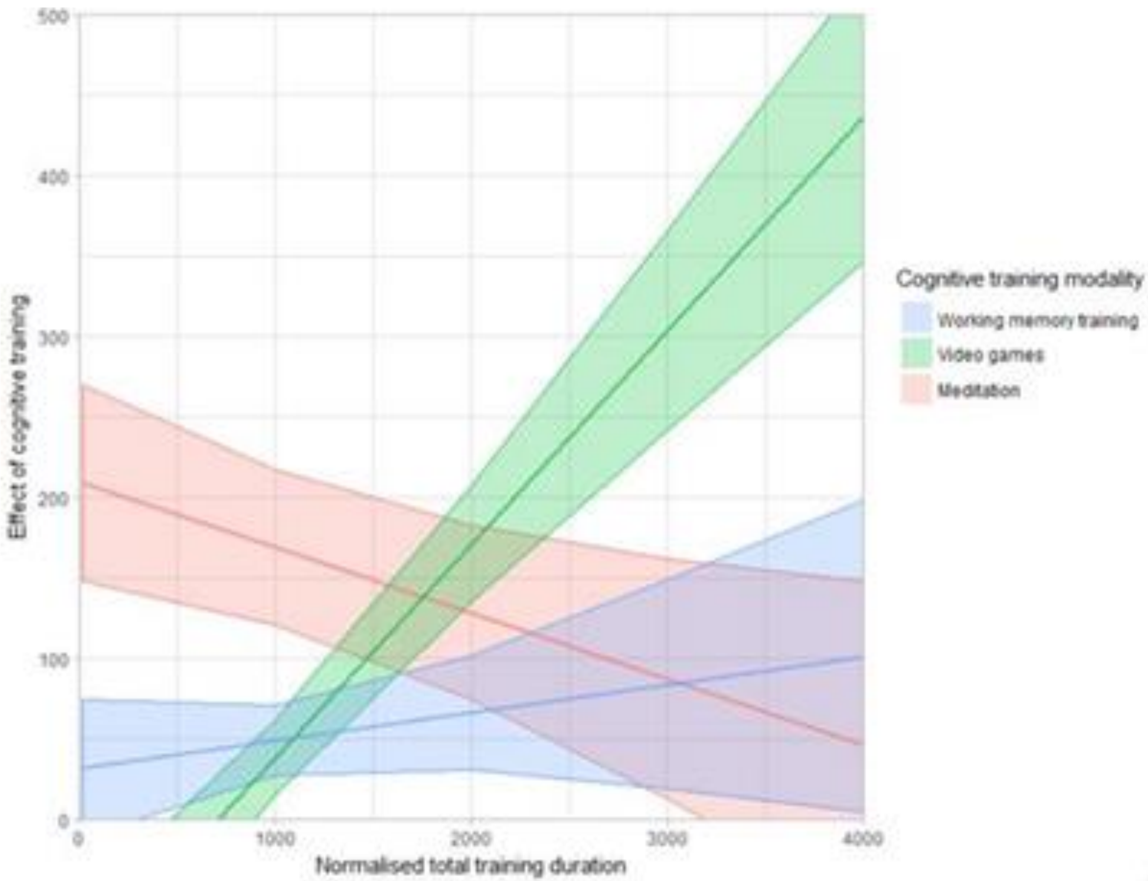
Heterogeneity: $Tau^2 = 0.1392$; $Chi^2 = 129.75$, df = 28 ($P < 0.01$); $I^2 = 78\%$



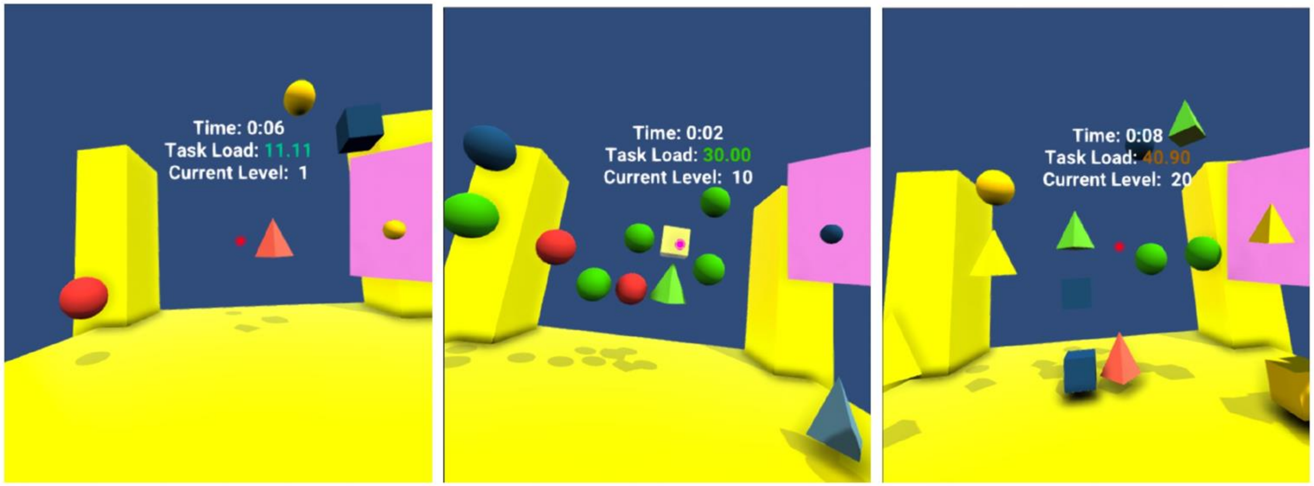
Overall transfer: 0.5, medium effect size

Transfer benefits from cognitive training: Systematic Review & Meta-Analysis

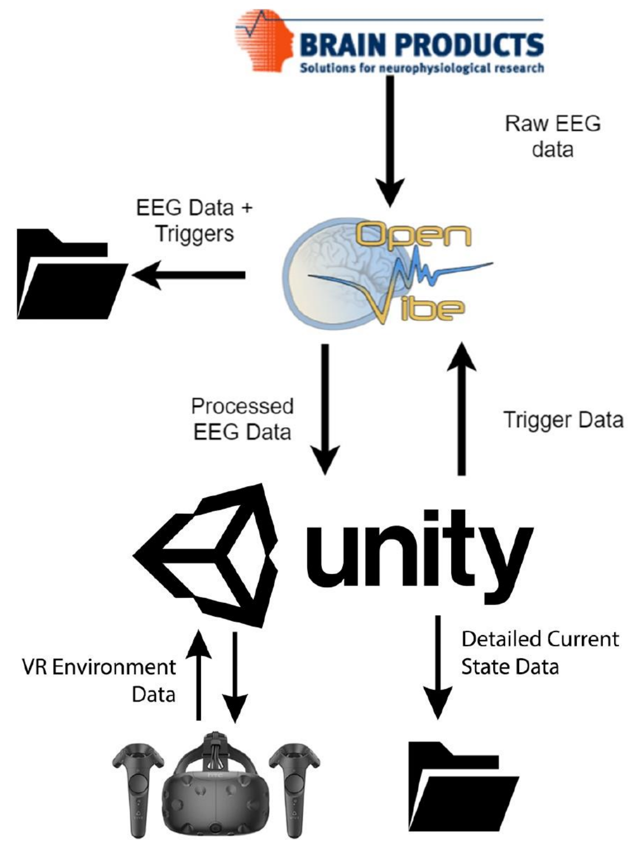
Training duration and Transfer Effects



Adaptive VR System for Training



(a) Level 1 (b) Level 10 (c) Level 20



We have developed an adaptive VR system for training

- Integrates commercial VR + EEG systems
- Target detection task in VR
- Complexity of the task scaled depending on cognitive ability
- System tested in pilot and full user studies

Adaptive VR System for Training

Online measurement of alpha power during target acquisition task:

- Monitoring of overall amount of attentional resources required for target discrimination amongst distractor stimuli
- Titration of task difficulty to ensure that training is adaptive (↓ alpha, ↑ difficulty; Haegans, Luther & Jensen, 2012)

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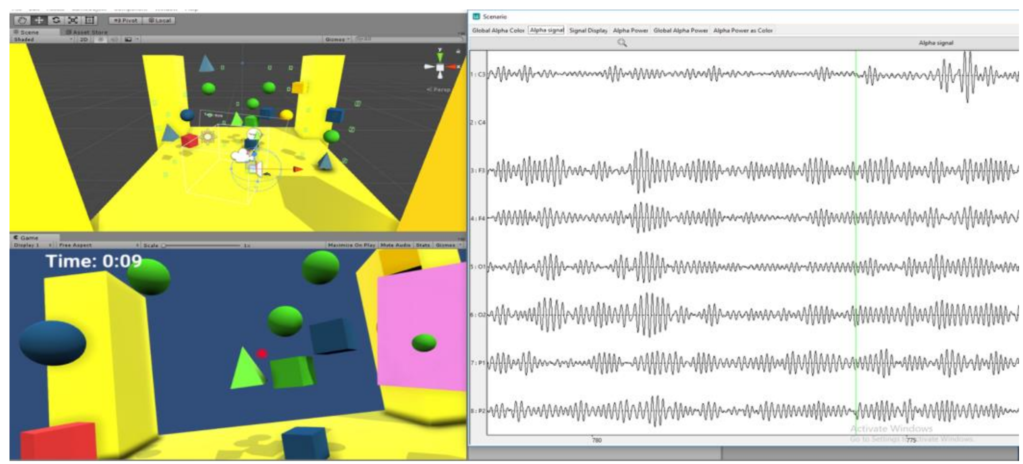
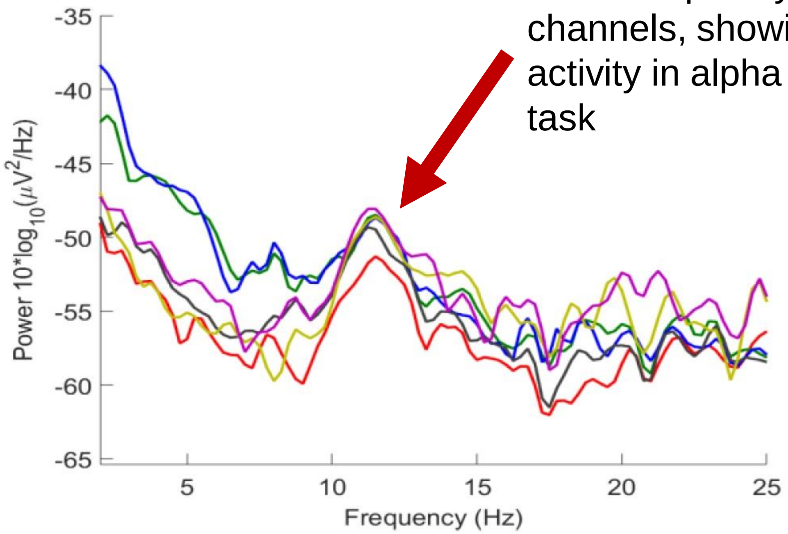


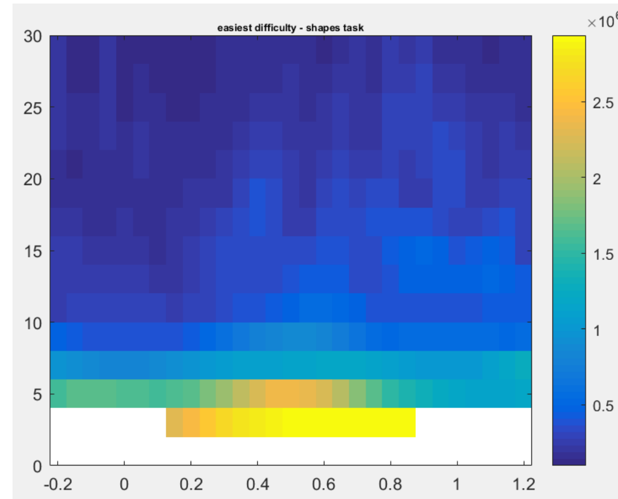
Adaptive VR System for Training

Experiment Results

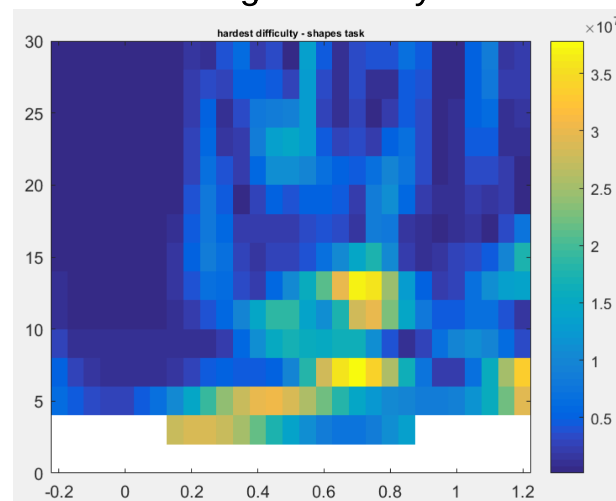
EEG Frequency activity across 6 channels, showing increased activity in alpha band during search task



Low Difficulty



High Difficulty



User study conducted

- N=15(8F)
- mean age 27.54(6.85), range = 20-41

Key results

- Alpha power significantly increased in highest versus lowest difficulty levels of task, $t(13)=2.23, p=0.01$

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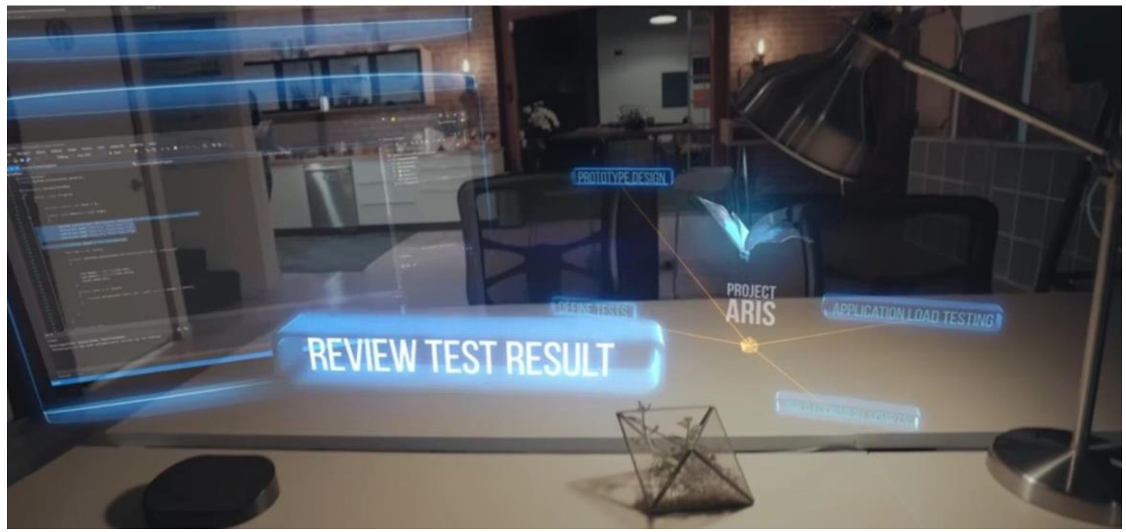
Prototype EEG + AR System

Modified existing VR system to work in AR
- Same underlying software
- Used higher contrast colours
- Moved test area to accommodation EEG hardware

Using Meta2 see-through display
- Wide field of view (90 degree)
- Tethered to PC (better graphics)
- Different controller, handheld device
- Images difficult to see against reality

Pilot testing underway
- Results still to be analyzed
- Full testing December - January



Ongoing Work

1: Using EEG to Measure Cognitive Load in AR

- User study using system developed for Milestone 2B
- Publication for ISMAR 2019 conference - due March 2019

2: *Develop Simulated Warfighting Environment*

- Realistic AR/VR training environment - Milestone 2B, due May 2019
- Target acquisition in realistic urban environment, simulating virtual range

3: *Simulate Autonomous Systems*

- Integrate simulated UAV into VR training - Milestone 2C, due May 2019

4: *Multiple User EEG Capability*

- Integrate multiple users into VR EEG training environment - Milestone 2D, due Nov 2019

5: *Cognitive Training*

- Individual predictors of cognitive training outcomes - Milestone 3E, due May 2020

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Research Outputs (2018)

Dey, A., Chen, H., Billinghurst, M., & Lindeman, R. W. (2018, October). Effects of Manipulating Physiological Feedback in Immersive Virtual Environments. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play*(pp. 101-111). ACM.

Gerry, L., Ens, B., Drogemuller, A., Thomas, B., & Billinghurst, M. (2018, April). Levity: A Virtual Reality System that Responds to Cognitive Load. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (p. LBW610). ACM.

Dey, A., Chatburn, A., Thomas, B., Billinghurst, M., Exploration of an EEG-Based Cognitively Adaptive Training System in Virtual Reality (Submitted to IEEE VR)

Defence Human Sciences Symposium 2018

Immink, M.A., Chatburn, A., Pomeroy, D., Thomas, B., Chahl, J, Schlesewsky, M., Bornkessel-Schlesewsky, I., Billinghusrt, M. **A systematic review and meta-analysis of transfer effects from working memory, video game and meditation-based modalities of cognitive training**

Chatburn, A., Immink, M.A., Pomeroy, D., Thomas, B., Bornkessel-Schlesewsky, I., Schlesewsky, M., Chahl, J, Billinghusrt, M. **Adaptive virtual reality cognitive training based on real time alpha power measurement**