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Message From Department of Defence

Dr Nick Beagley
Research Leader Land Human Systems

It has been a year of challenges and change and I for one find this year's Defence Human Sciences Symposium to be a comforting indication of a return to familiar activities and a reconnection with the diverse and distributed members of the Human Sciences community.

It is my pleasure to welcome everyone back to this year's event, albeit changed to a virtual gathering. I am sure that we are all looking forward to the face-to-face interactions that do so much to grow and strengthen the links across this community, but for the moment we must adapt.

For DHSS2020 we have the opportunity to further develop our mastery of the medium. Given our shared interest in "all things human", many of our community are likely have particularly relevant insights into how best to take advantage of the opportunities of virtual communication tools and how best to adapt to and overcome their limitations.

More than anything else, I would encourage people to resist the urge to multi-task over the course of the symposium. Whilst it can be tempting to answer an email or scan a headline there is a price to be paid for divided attention. Although I acknowledge my bias, in my view, the DHSS continues to go from strength to strength each year.

There is plenty in this year's program to interest and inform the toughest of crowds. The real richness of these events comes from your active engagement. Please take the time to consider, and question, and build upon what you hear through dialogue with the presenters. Whilst we don't have the opportunity to debate a point over coffee and cake in the break, the chat functions of these virtual tools and our increased capacity to hold side discussions by VTC, email, etc. should be embraced.

The strength of the Human Sciences community is built on the diversity of its thinkers and their ability and willingness to creatively engage. I would like to thank the many organisers who have donated their time to realising this event, to Deakin University for hosting this forum, and to each of you for your participation. Together we will achieve more.

Nick Beagley

Message From Deakin University

Alfred Deakin
Professor Julie Owens
Deputy Vice-Chancellor, Research

Established in 1974, Deakin University was named after the leader of the Australian Federation movement and the nation's second Prime Minister, Alfred Deakin.
Deakin University has five campuses, one in Melbourne's eastern suburbs, two in the port city of Geelong, one in Warrnambool on the south-west coast of Victoria, and more than 15,000 students study predominantly online as part of Deakin's Cloud Campus.
With over 60 000 students Deakin is one of Australia's largest universities and is consistently ranked in the top 1% of the world's universities.

As an Australian university with global impact, Deakin is translating its research into impact on knowledge and into valuable commercial outcomes that will drive the innovation Australia's economy needs now and into the future. Research at Deakin focusses on innovation and robust partnerships with industry and business, and it is building a formidable international reputation in areas of emerging national social, economic and political priority, through its core focus areas of health, sport, carbon fibre, energy, defence and cyber security.

Deakin is proud to partner with Defence Science and Technology (DST) as the host organisation for the 2020 Defence Human Sciences Symposium (DHSS). In 2020 we have endured some very difficult times, with bushfires in January through to the once in a generation pandemic that has crippled the world, with devastating consequences.
We host the 2020 DHSS in a "Virtual" environment and hope you will enjoy the very different but just as exciting symposium in 2020.

Deakin is committed to continuing to develop our research and innovation capabilities in defence related disciplines as we further build productive long-term partnerships with Defence and the defence industry, through our world class research institutes and strategic research centres.

DHSS Program - 7th December

DHSS Program Day 1– 7th December 2020 (all times AEDT)	
0930-0945	*Presenter preparation time and session brief* *Ms Jodi Morgan - Manager, Commercial Events, Deakin University*
Opening Session **Chair: Dr David Crone, Department of Defence**	
0945-0955	Welcome – Dr Nick Beagley, Research Leader Land Human Systems
0955-1005	Opening Address – Dr Peter Shoubridge, Chief Land Division, Department of Defence
1005-1015	Opening Address – Alfred Deakin Professor Julie Owens, Deputy -Vice Chancellor- Research
Session 1 – Physiological Monitoring **Chair: Professor Kon Mouzakis, Deakin University**	
1000-1015	*Presenter preparation time and session brief* *Ms Jodi Morgan - Manager, Commercial Events, Deakin University*
1015-1035	Factors predicting injury and attrition of recruits across 12 weeks Basic Military Training (Luana Main, Deakin University)
1035-1055	Monitoring allostatic load across basic military training using heart rate variability (Sean Corrigan, Deakin University)
1055-1115	Utility of biological markers to track psychophysiological stress responses during elite military training (Kagan Ducker, Curtin University)
1115-1135	Investigating the cumulative and combined effects of the multi-stressor 1RTB training military environment and the associated effects on the gut microbiome, microbiota metabolites and aspects of cognition in Australian Army recruits: Study protocol (Matthew Cooke, Swinburne University)
1135-1155	The effect of sex and load on coordination variability during load carriage (Brooke Hoolihan, Uni of Newcastle)
1155-1205	**Break (10mins)**
1205-1215	Reliability and validity of a submaximal shuttle running test for elite athletes (Anthony Leicht, James Cook Uni)
1215-1225	An evaluation of the Apple watch and the WHOOP for the quantification of sleep, overnight heart rate variability and physical activity (Spencer Roberts, Deakin University)
1225-1235	The health and performance consequences of Australian Special Forces Selection and training courses (proposed research) (Angela Uphill, Edith Cowan University)
1235-1245	Exploring Simulated Submarine Motion and Sleeping Berth Orientation on Sleep (Raymond Mathews, University of South Australia)
1245-1330	**Lunch Break (45 mins)**
1330-1400	Keynote Presentation - BRIG Glenn Ryan, Director General Training and Doctrine.
Session 2 – Biomechanics & Load Carriage **Chair: Dr Spencer Roberts, Deakin University**	
1345-1400	*Presenter preparation time and session brief* *Ms Jodi Morgan - Manager, Commercial Events, Deakin University*
1400-1420	Monitoring Mechanical Load in a Military Population using a single IMU (Andrew Gray, Athletic Data Innovations)
1420-1440	The use of wearable technology in the evaluation of gait patterns of soldiers during weighted locomotion (Samantha Betts, Department of Defence)
1440-1500	Are there kinematic sex differences across the gait cycle during overground load carriage? (Danielle Vickery-Howe, LaTrobe University)
1500-1520	Impact absorption analysis during the gait wearing two military boots with and without load (Douglas Silva Sizenando, Brazilian Army)

1520-1540	Toward Optimal Selection of an Assistive Device to Minimise Risk of Injury and Enhancement of Performance (Hossein Mokhtarzadeh, University of Melbourne)
1540-1600	Break (20 mins)
1600-1610	Muscle activation differences in raising and aiming of a rifle (Jemma Coleman, Department of Defence)
1610-1620	High-quality human motion measurement in the field using wearable sensors (David Ackland, University of Melbourne)
1620-1630	A neck load monitoring system for helmeted aircrew (Phil Newman, University of Canberra)
1630-1640	Quadriceps muscle oxygenation may be used as a proxy for knee joint torque during load carriage: a pilot study (Alessandro Garofolini, Victoria University)
1640-1650	Validation of a machine learning algorithm to enhance decision making in the management of medial tibial stress syndrome (Angus Shaw, University of Canberra)
1650-1700	Musculoskeletal Injuries in the Australian Defence Force- “No Worries Mate!”? (Phil Newman (University of Canberra)
1700-1715	Housekeeping (if required)
1715	Day 1 Close

DHSS Program - 8th December

DHSS Program Day 2 – 8th December 2020 (all times AEDT)	
Session 3 – Cognitive Performance & Enhancement Chair: Dr Chris Best, Department of Defence	
0925-0940	*Presenter preparation time and session brief* *Ms Jodi Morgan - Manager, Commercial Events, Deakin University*
0940-1000	Recovery of cognitive performance following multi-stressor military training (James Tait, Deakin University)
1000-1020	Transcranial direct current stimulation of prefrontal cortex augments multi-session single/dual-task training and induces near transfer: A dosage study (Shane Ehrhardt, University of Queensland)
1020-1040	Cognition research in the cyber domain: a scoping review (Ben Hoggan, Department of Defence)
1040-1100	The impact of sleep loss on performance monitoring and error-monitoring: A systematic review and meta-analysis (Johanna Boardman, Monash University)
1100-1120	Identifying neurobiological markers of high performance on an undersea decision-making task (Zachariah Cross, University of South Australia)
1120-1130	Break (10 mins)
1130-1140	Enhancing Sensemaking: Supporting Distributed Groups in the Future Operating Environment (S Attfield, UK Middlesex University)
1140-1150	Visualisation and Quantification of Gaze-strategies in a Dynamic Environment (Rakesh Veerabhadrappa, Deakin)_
1150-1200	Multi-modal Cognitive Training with an Immersive Virtual Reality Marksmanship Task and Mindfulness Meditation (Maarten Immink, UniSA)
1200-1210	Genetic Markers of Cognitive Fitness (Liliana Ciobanu, University of Adelaide)
1210-1220	Understanding demands, resources, and resilience during deployment at sea: Preliminary outcomes from interview data (Gavin Hazel, Macquarie University)
1220-1230	Effects of the Human Gut Microbiota on Mental Wellbeing: A Scoping Study (Katie Tooley, Department of Defence)
1230-1240	Translating Cognitive Fitness Framework for Dual-use Application: A Performance-Focused Intervention for Athletes Affected by COVID-19 Disruption (Jeff Bond, Australian Psychological Society)
1240- 1330	Lunch Break (50 mins)
1330-1340	Exploring the intra-individual reliability of tDCS; A Registered Report (Nick Willmot, Department of Defence)
1340-1350	Neural Substrates of Cognitive Enhancement via Combined Brain Training and Non-Invasive Brain Stimulation (Yohan Wards, University of Queensland)
1350-1400	The power of panorama? Exploring visual search tasks in a simulated submarine control room (Steph Chen, University of Western Australia)
1400-1410	Investigating the role of individual alpha frequency on information processing in a virtual reality navigational setting (Emma Pretty, University of South Australia)
1410-1420	Break (10 mins)
Session 4 – Training & Simulation Chair: Dr Simon Parker	
1405-1420	*Presenter preparation time and session brief* *Ms Jodi Morgan - Manager, Commercial Events, Deakin University*
1420-1440	The effect of mobile app-based multitasking training on situation awareness and performance in Army personnel (Stephanie Black, University of Western Australia)

1440-1500	Exploring the utility of mobile apps for training and learning in the Australian Army (Jodie Stevens, University of Adelaide)
1500-1520	AARs - Facilitating Team Learning for Improving Performance in Combat Forces (Mick Reilly, Massive Pty Ltd)
1520-1540	Performance Edge VR: An implementation trial to evaluate efficacy and usability of a modular biofeedback-enhanced stress management platform (Rohan Walker, University of Newcastle)
1540-1600	Using Epistemic Network Analysis to Model Individual and Team Performance (Zachari Swiecki, Monash University)
1600-1610	**Break (10 mins)**
1610-1620	Mixed Reality in Distributed Teams (Ellyse Greer, University of South Australia)
1620-1630	The role of automated human-performance measurement for enhancing training effectiveness and warfighter readiness (Simon Hosking, Department of Defence)
1630-1700	Housekeeping (if required)
1700	Day 2 Close

DHSS Program - 9th December

DHSS Program Day 3– 9th December 2020 (all times AEDT)	
0915-0940	*Presenter preparation time and session brief* *Ms Jodi Morgan - Manager, Commercial Events, Deakin University*
Session 5 – Autonomy & Teaming **Chair: Dr Sam Huf**	
0940-1000	EEG-based Evaluation of Virtual Unmanned Vehicle Control Systems (James Baumeister, University of South Australia)
1000-1020	Are Two Heads Always Better Than One? (Sabina Kleitman, University of Sydney)
1020-1040	Error-related brain activity differs when observing a human and autonomous system perform the same target recognition task (Daniel Rogers, University of South Australia)
1040-1100	Telexistence: Mitigating the Human Risk Associated with Operating in Hazardous Environments (Liam Elliott, Dstl, UK)
1100-1120	**Break (20 mins)**
1120-1140	Applying the ATTA-bot (Acceptance, Trust, Tolerance, Anthropomorphism) framework to evaluate the introduction of a Logistics Robotic into Air Force 36 Squadron (Max Cappuccio, University of New South Wales)
1140-1150	Mitigating Automation Bias With Explanation (Mor Vered, Monash University)
1150-1200	Development of a computational model of tactical decision making for human-AI teaming (Andrew Neal, University of Queensland)
1200-1210	From human-centred to team-centred: designing cyber-human teams for decision superiority (Brittany Huber, Swinburne University)
1210-1220	Hybrid Human-AI Teaming in Real-Time Strategy Games (Penny Kyburz, Australian National University)
1220- 1320	**Lunch Break (60 mins)**
Session 6 – Research Methods & Measurement **Chair: Dr Susannah Whitney**	
1305-1320	*Presenter preparation time and session brief* *Ms Jodi Morgan - Manager, Commercial Events, Deakin University*
1320-1340	Building a Transdisciplinary Expert Consensus on the Neurocognitive Drivers of Performance Under Pressure: An International Delphi Study (Lucy Albertella, Monash University)
1340-1400	A Flexible Gaming Environment for Reliably Measuring Cognitive Control (Lindsay Wells, University of Tasmania)
1400-1420	Developing Psychometric Measures of Resilient Performance Capability: Acute Readiness and Army Resilience Traits Scales (Richard Keegan, University of Canberra)
1420-1440	Informing Future Royal Australian Navy (RAN) Operations Room Design through Field Data Collection Exercises: Lessons Learned and Future Recommendations (Suzanne Hanna Department of Defence)
1440-1500	Implementing Data Analytics to Maximise Human Performance (Katrina Hinde, UK Defence Science and Technology Laboratory)
1500-1520	**Break (20 mins)**
1520-1530	A Novel Gaze Processing Framework Using Crosscorrelation and Recurrence Quantification Analysis to Differentiate Expert Performances (Rakesh Veerabhadrappa, Deakin)
1530-1540	Predicting Resilience in the Face of Uncertainty: Who is Adapting well to COVID-19? (Sean Drumomond, Monash Uni)
1540-1550	Colour vs green symbology in head mounted displays - does it make a difference? (Amanda Douglass, Deakin)

1550-1600	Measuring real-time cognitive load in naturalistic environments: initial pilot results from EEG systems worn under a military helmet (Alex Chatburn, UniSA)
1600-1610	Delivering Human Sciences Impact for the Warfighter: Outcomes from Defence Human Sciences Symposium 2019 Panel Discussion (Philip Temby, Department of Defence)
1610-1620	So you need soldiers for research? (Alison Fogarty, Department of Defence)
1620-1630	Application of sensor technologies in extreme workplace environments (Liam Ashby, Curtin University)
1630-1640	Resilience, adaptability and cognitive readiness in the face of COVID-19: Validating CF2 constructs as predictors of lockdown readiness and mental well-being (Sabina Kleitman, University of Sydney)
1640-1700	Break (10 mins)
Closing Session – 'Achieving More Together' Chair: Dr David Crone, Department of Defence	
1645-1700	*Presenter preparation time and session brief* *Ms Jodi Morgan - Manager, Commercial Events, Deakin University*
1700-1730	Special Presentation and discussion. The Human in Contested Environments – Dr Axel Bender (STaR Shot Leader, Operating in a Contested Environment, Department of Defence)
1730-1745	Symposium Awards & Closing Remarks – Dr Nick Beagley (Department of Defence)

DHSS 2020 – Abstracts | Day 1

Session 1 – Physiological Monitoring

Factors predicting injury and attrition of recruits across 12 weeks Basic Military Training.

Luana C. Main, PhD [a]. Jamie L. Tait *, PhD [b]; Sean Bulmer [b], Paul B Gastin, PhD [c]; Jace R. Drain, PhD [d]

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Background: Basic military training (BMT) prepares recruits for the demands of military service, by exposing them to physically and cognitively challenging activities. However, ensuring a balance between training workload and recovery during BMT is necessary to avoid maladaptive training responses (e.g., illness or injury). Collectively these adverse outcomes can lead to a loss of training days, delays in timely march out, and training attrition, which may compromise organisational capability. Previously identified predictors for injury during BMT have typically included demographic and performance data collected at a single time point, such as commencement of BMT, rather than ongoing data collection across BMT.

Aim: The aim of this study was to determine individual risk factors for injury during BMT from a suite of objective and subjective markers. A secondary aim was to explore the implications of injury on attrition.

Method: This study was part of a broader project that monitored load, adaptation and performance across BMT. 48 male and female recruits enrolled in the 12-week Australian Army BMT course consented to participate in this study. Across the 12-week training program injury, illness, attrition and demographic data were collected. Objective measures included weekly salivary cortisol and testosterone, daily step counts, cardiorespiratory fitness and muscular endurance (in weeks 2 and 8). Perceptions of well-being, recovery, workload, fatigue, and sleep were assessed with questionnaires such as the Short Recovery Stress Scale (SRSS; Kellmann & Kolling, 2019), administered weekly, and the Depression Anxiety and Stress Scale (DASS; Lovibond & Lovibond, 1995) administered monthly. Baseline and mean scores across BMT were evaluated as predictors of injury (n=18 injuries from n=13 participants) using generalized linear regressions, with a backward elimination procedure identifying independent risk factors.

Results: 38 recruits completed BMT, 13 became injured and there was a subsequent delay on march out for seven participants. Of the 18 injuries recorded, 55% of these occurred in the first four weeks, only one injury occurred in the middle of the program (weeks 5 to 8), with the remainder <30% in the final four weeks. The timing of two injuries was undefined. Multiple risk factors for increased injury during BMT were identified, including female sex [3.7 times at risk, $p=0.002$], however this was no longer significant when VO_2max was controlled for as a covariate. Higher concentrations of bedtime cortisol ($p<0.001$), pre and post-sleep fatigue ($p<0.05$), and perceived stress ($p<0.05$) were also risk factors for increased injury. Higher predicted VO_2max (i.e. ≥43.9ml.kg.min^{-1}) and perceptions of recovery at baseline were associated with lower injury risk.

Conclusions: Ongoing monitoring with a select suite of markers may have utility in forewarning risk of training maladaptation in recruits. Specifically, real-time monitoring of recruits who may be vulnerable to injury could be used to underpin decisions on whether countermeasures, such as individualised opportunities for recovery, should be applied to mitigate maladaptation and attrition during BMT. These easily administered and cost-effective subjective measures could contribute to prediction models of injury and attrition, and complement previously identified demographic and performance-based risk factors.

References:

Lovibond, S.H. & Lovibond, P.F. (1995). *Manual for the Depression Anxiety Stress Scales. (2nd. Ed.)*. Sydney: Psychology Foundation.

Kellman, M., & Kolling, S. (2019). Chapter 5: The Short Recovery Stress Scale. *Recovery and Stress in Sport: A Manual for Testing and Assessment*, Routledge, London.

Monitoring allostatic load across basic military training using heart rate variability

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Background: An ongoing challenge for the Australian Defence Force is the management of personnel to optimise and maintain performance, whilst also ensuring ongoing health and wellbeing. In the Australian Army 74% of injuries are sustained during physical and combat-related training, with a high prevalence of overuse injuries (Schram, Pope, & Orr, 2019). Thus, it has been identified that there is a need for markers that can help discern between adaptive and maladaptive responses in defence populations; which would improve personnel management to reduce these overuse injuries. Heart rate variability (HRV) has previously shown sensitivity to acute stressors in defence personnel (Diaz- Manzano, Fuentes, Fernandez-Lucas, Aznar-Lain, & Clemente-Suárez, 2018). However, the suitability of HRV as a measure of allostatic load in this context has yet to be shown. If HRV proves a suitable measure of allostatic load it could provide utility in managing adaptive and maladaptive responses in defence populations.

Aim: To determine if 1) HRV was sensitive to changes in recruit's weekly workload across the Australian Army 12-week Basic Military Training (BMT) course, and 2) whether changes in physical fitness impacted these relationships.

Method: 48 recruits (25.3 ± 7.1 years, body mass index; 24.8 ± 4.9 kg/m^2, 39 males and 9 females) participated in the study. Recruits reported daily measures of cognitive load (NASA TLX) and perceived exertion (RPE) for the duration of the BMT course. Weekly physical workload and subjective wellbeing were measured using ActiGraph GT9X Link accelerometers and the Multi-component Training Distress Scale (MTDS), respectively. The natural log of root mean square of successive differences (LnRMSSD) was used for HRV and was recorded during sleep every Friday, Saturday and Sunday night. The first estimated period of slow wave sleep on each night was used for analysis. (Brandenberger, Buchheit, Ehrhart, Simon, & Piquard, 2005). The BMT fitness test battery consisting of the shuttle run, maximum push up and sit up tests was completed in weeks 2 and 8 of the program. Predicted $\dot{V}O_2$ max values were calculated from shuttle run performance and used for analysis. Data was analysed using a paired t test for fitness changes and linear mixed models.

Results: 31 recruits had sufficient data for 7 or more weeks of BMT and were included in the analysis. Predicted $\dot{V}O_2$ max increased on average by 5.5 ± 6.3 ml/kg/min ($t(29)=4.76$, $p<0.001$) between weeks 2 and 8. Increases in weekly measures of RPE (ß=0.068, p=0.003) and subjective fatigue (MTDS fatigue) (ß=0.034, p=0.007) corresponded with increases in weekly LnRMSSD. Measures of cognitive load (NASA TLX), energy expenditure, % of time spent in sedentary, light, moderate and vigorous zones all had no effect on weekly LnRMSSD (P>0.05). Increases in predicted $\dot{V}O_2$ max values corresponded with decreases in weekly LnRMSSD (ß=-0.036, p=0.007). Introducing physical fitness changes decreased the influence of RPE to a non-significance level (ß=0.045, p=0.064) and increased the influence of MTDS fatigue (ß=0.045, p=0.001) on LnRMSSD.

Conclusions: HRV appeared to be more sensitive in detecting subjective recruit responses to BMT workloads than the objective measures of activity. This supports the theory that HRV may have utility in monitoring individual allostatic load.

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Brandenberger, G., Buchheit, M., Ehrhart, J., Simon, C., & Piquard, F. J. A. N. (2005). Is slow wave sleep an appropriate recording condition for heart rate variability analysis? *Autonomic Neuroscience: Basic and Clinical, 121*(1-2), 81-86.

Diaz-Manzano, M., Fuentes, J. P., Fernandez-Lucas, J., Aznar-Lain, S., & Clemente-Suárez, V. J. (2018). Higher use of techniques studied and performance in melee combat produce a higher psychophysiological stress response. *Stress and Health: Journal of the International Society for the Investigation of Stress*.

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Utility of biological markers to track psychophysiological stress responses during elite military training

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Background: Physiological markers of stress may have utility for tracking psychophysiological stress in occupational settings, yet little is known about using these markers in military populations, and more specifically in elite military settings. Our objective was to examine the utility of cortisol (hair and saliva) and testosterone (saliva) as biological markers for quantifying the stress response in a sample of Special Forces trainees. This objective was driven by training staff interest in whether physiological indices at different time points corresponded with their perceptions of the more demanding parts of training.

Method: Twenty-nine males (26.25 $\pm$ 2.67 years) who were undertaking a 15-month SF training course participated in the study. We captured assessments of hair cortisol concentration (HCC) on 9 occasions across the first 12 months, and salivary cortisol and testosterone on 4 occasions across a 4-month period. Participants provided three saliva samples per day (2 mL passive drool), immediately upon waking, 30 min post awakening (salivary cortisol only), and immediately before bed. All hair and saliva samples were analysed in duplicate using the enzyme-linked immunosorbent assay method. We chose to utilise the cortisol awakening response (CAR) and diurnal cortisol slope to represent the function of the autonomic nervous system (ANS) and hypothalamic-pituitary-adrenal (HPA) axis activity [1]. Morning peak and diurnal testosterone slope were chosen to reflect anabolic hormone function [2].

Results: Median levels of HCC appeared to track periods of low and high stress effectively. The peak stress level occurred at time T1 (i.e., following pre-selection course), then again at T4 (strenuous field- based activity). However, there is a time lag in reaching peak stress levels that is measured in the month or two following a very stressful period. These levels also track recovery from these stressful periods effectively, albeit with a time lag, as they correspond with periods of relative rest (e.g., T2=recovery week; T6=recovery from two demanding field-based activities). The overall temporal trend of stress responses was captured relatively similarly by HCC and self-reported stress. Both salivary CAR and cortisol diurnal slope recorded the lowest median levels in recovery week, reflecting a blunting in the responsiveness of the HPA axis and ANS in response to the stress of pre-selection. Both markers showed a recovery in the responsiveness of the systems that persisted until T3 (another field-based activity) before again being blunted by the end of T4. Importantly, there was significant individual variation in these responses throughout the sample. Peak testosterone was depressed following selection and recovered back to peak concentrations by the end T2. The stress at T3 led to a decrease in testosterone that persisted throughout T4 (field-based activity).

Conclusions: Overall hair cortisol levels appear to track periods of stress and recovery well in this population, albeit with a time lag. Salivary testosterone appears to track stress in military personnel to an acceptable level, whereas salivary cortisol markers showed some promise, however individual variation appears to be significant. These findings suggest biological markers may have utility for monitoring stress responses and informing training loads of military personnel. Further research is required to address individual differences and time lag issues.

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Investigating the cumulative and combined effects of the multi-stressor 1RTB training military environment and the associated effects on the gut microbiome, microbiota metabolites and aspects of cognition in Australian Army recruits: Study protocol

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Background: Enhancing or preserving cognition of the soldier, especially in stressful and contested environments, is an Australian Army priority research area. The human microbiota is considered an emerging biotechnology which may be leveraged to enhance warfighter cognitive and physical performance and resilience.

Purpose: The proposed research will use a multi-biological systems approach to comprehensively characterise changes to the host (warfighter) and its microbiome following exposure to military-relevant stressors, and link these to military-relevant cognition, well- being and job performance measures.

Methods: Voluntary and informed consent will be sought from approximately 160 1RTB recruits completing basic training at Army Recruit Training Centre, Kapooka, New South Wales. Applying a longitudinal exploratory study design, data will be collected on biological samples (saliva, blood, faecal and urine) and socio-demographic, psychological and physical measures using a range of tests/questionnaires during Week 1, 6 and 11/12. Army recruits will complete computerised cognitive tasks designed to assess core cognitive functions and higher order processes, such as fluid reasoning, visual processing and attention, short-term and long-term memory, processing speed, executive function, reaction/decision speed and task switching. In addition, recruits will also complete self-report questionnaires and surveys about their health-related quality of life (SF-36), mood state (POMS) and grit (Duckworth Grit Questionnaire), sleep quality (PSQI) and nutritional intake (food frequency questionnaire (FFQ)/ food dairy). Blood samples will be analysed for a range of metabolites (targeted and untargeted metabolomics), pro-and anti- inflammatory cytokines/chemokines (i.e. C-reactive protein, tissue necrosis factor-α, Interleukin 1- beta, Interleukin 1-6), and indirect markers of intestinal permeability (i.e. lipopolysaccharide). Faecal and saliva samples will undergo 16S rRNA amplicon sequencing for microbiota analysis. Urine samples will be analysed for a range of metabolites (targeted and untargeted metabolomics). Self- report symptoms of irritable bowel (IBS) will also be mesured to determine if changes in the microbiota and its function manifest into symptoms that may impact daily activities. As it is expected that 1RTB recruits may experience a heightened level of stress in the days leading up to arrival at Kapooka, but also within the initial days of experiencing military life, approximately 160 civilian participants of similar age and demographic will be recruited as a control group to investigate potential stress-induced differences at baseline.

Key Implications: The proposed study will address a major gap in our understanding in the dynamic relationship between environment-warfighter- microbiome interactions. Furthermore, outcomes from the research will address additional gaps, specifically: (1) what does a resilient/preserved cognitive performers' microbiome look like? and (2) those who are at risk, or who develop less-desirable brain behaviours (i.e. stress, anxious and depressed) during training, does this occur as a result of gut dysbiosis?

The effect of sex and load on coordination variability during load carriage

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Background: Load carriage related injuries in the military directly impact personnel's availability for service, with 34% of soldiers sustaining one across their career (Orr et al., 2017). Lower limb coordination variability (CV) has been equivocally linked to injury, with both higher and lower CV shown when compared to healthy controls (Davis et al., 2019; Van Emmerik et al., 1999)Load carriage has been shown to increase CV in lower-back couplings (Yen et al., 2012), however, its effect on lower-limb coordination is unknown. Furthermore, sex has been reported to affect CV during non-loaded locomotion tasks (Boyer et al., 2016; Pollard et al., 2005), indicating potential sex- load interactions.

Aim: Investigate the interaction between sex and load on CV during load carriage.

Method: Twenty-five participants (12 female, 13 male) completed three treadmill-based walking trials wearing body-borne external load (0%, 20% and 40% of body weight [BW]) at self-selected walking speed. A Vicon motion capture system tracked marker trajectories and a lower-body direct- kinematic model calculated sagittal-plane joint kinematics of the hip, knee, and ankle. The standard deviations of Continuous Relative Phase (CRP) quantified lower body CV across 19 strides for the following couplings: Hip-Knee, Knee-Ankle, Thigh-Shank, Shank-Foot. The mean CRP standard deviation across the gait cycle provided a discrete measure of CV. Mixed-design ANOVAs (⍰=.05) assessed the interaction between sex and load using SPSS software. Paired comparisons were then conducted where significant interactions or main effects were found. Data are presented as mean difference ± standard error.

Results: Significant interaction effects were present for all segment angle couplings (p<.05). For Thigh-Shank, males had significantly higher CV than females in the 0%BW condition (0.9±0.3°), while CV was higher in females for the 40%BW condition compared to 0%BW (0.9±0.2°) and 20%BW (0.7±0.2°). For Shank-Foot, there were no sex differences, while CV was higher in the females at 40%BW than both 0%BW (0.7±0.2°) and 20%BW (0.5±0.1°). There were no interaction effects for either the Hip-Knee coupling (p=0.059, η^2 =0.116) or the Knee-Ankle coupling (p=0.091, η^2 =0.099), nor a main effect of sex (p=0.380 and p=0.794, respectively). There was a significant main effect of load for both the Hip-Knee coupling (p<0.001, η^2 =0.283) and the Knee-Ankle coupling (p=0.023, η^2 =0.151) with the 40%BW condition having higher CV than the 0%BW (Hip- Knee: 0.8±0.2°) and 20%BW conditions (Hip-Knee: 0.8±0.2°; Knee-Ankle: 0.9±0.3°).

Conclusions: The female participants displayed less lower-limb CV than males in the 0%BW, condition supporting that females displayed lower CV during unloaded cutting tasks (Pollard et al., 2005). Lower-limb CV also increased with load in females, which agrees with past observations that CV of the trunk, pelvis, and thigh increases with load (Liew et al., 2020; Yen et al., 2012). This likely reflects the load perturbing the neuromuscular system, and the female participants exploring movement solutions to meet the task demands. The lack of change in CV in the male participants could not be explained and warrants further investigation into the sex-load interaction on CV during load carriage.

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Reliability and validity of a submaximal shuttle running test for elite athletes

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Background: Elite athletes such as those in team sports and military undertake regular training to maintain and enhance performance. Regular monitoring of training adaptations provides practitioners with important feedback to optimise training. However, maximal exercise assessment protocols may contribute to fatigue accumulation and subsequent poorer training responses and/or performance. The use of submaximal testing protocols may provide practitioners with a superior tool to identify training adaptations without subsequent impact. Recently, a submaximal shuttle running test (SubRT) was developed to monitor elite athletes with its reliability and validity yet to be determined.

Aims: To examine the reliability and validity of the SubRT in elite athletes.

Method: Twenty-nine, male athletes from the same organisation volunteered and completed the SubRT three times (1-2 weeks between trials) and a field-based test of aerobic fitness/capacity. The SubRT consisted of: 8 x 40m shuttle runs (shuttle/15 seconds); 30 seconds of standing recovery; 8 x 50m shuttle runs (shuttle/15 seconds); and 60 seconds of standing recovery. Heart rate (HR) was recorded continuously via a telemetric system during the SubRT with peak and mean HR during each running and recovery bout recorded. The HR decline during recovery was examined in absolute and relative terms, as well as the slope of change. For the assessment of aerobic fitness/capacity, participants completed an intermittent shuttle run test (ISRT, five bouts of continuous running of 2 x 20m, 2 x 40m and 2 x 60m until a total distance of 1200m was completed in the quickest time). Reliability of the SubRT was determined by 1-way ANOVAs, intraclass correlation coefficients (ICC), coefficient of variation (CV), and measurement bias with 95% limits of agreement (LOA). Validity was determined from Pearson correlations between SubRT variables and ISRT time.

Results: Repeated SubRT trials resulted in similar mean running HR for each trial but significantly lower peak HR for running bouts one (149.88.5 vs. 154.410.0 bpm) and two (164.77.3 vs. 168.78.9 bpm) during the second compared to the first trial. Likewise, the mean HR during recovery bouts one (137.613.3 vs. 148.313.1 bpm) and two (143.19.1 vs. 154.910.3 bpm) were significantly lower for the second compared to the first trial. The absolute and relative HR decline during recovery bouts were significantly greater for trial two compared to trials one and three. When comparing SubRT trials, the ICC for peak and/or mean HR during running (>0.74) and recovery (>0.42) bouts were moderate to good while the CV (2-8%) and measurement bias and LOA were small-moderate. In contrast, the ICC and CV for the absolute/relative and rate of HR decline during recovery were poorer. Validity for the SubRT was weak with the peak HR difference between running bouts within the same SubRT trial significantly correlated with ISRT time (>-0.51, p<0.01).

Conclusions: This study demonstrated good reliability of the SubRT in terms of running and recovery peak and mean HR for elite athletes. Limited validity of the SubRT as an indicator of aerobic fitness/capacity was observed with further work needed to clarify this aspect.

An evaluation of the Apple watch and the WHOOP for the quantification of sleep, overnight heart rate variability and physical activity

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Background: Monitoring of soldier status has the potential to facilitate optimised performance outcomes through the evaluation and adjustment of training. Consumer-grade wearable devices that claim to accurately monitor individual health and/or fatigue status have become increasingly available. Many record specific bio-behavioural data such as total sleep, sleep efficiency, heart rate variability, overnight heart rate, and physical activity. These devices have become particularly popular in occupational settings where monitoring workers' health and fatigue is important. However, most commercially available devices have not been validated against 'gold standard' measures, and use proprietary algorithms to provide insights into an individual's health status.

Aim: to assess the validity of the WHOOP (2.0) and Apple (Series 3) watches for physical activity, sleep, and heart rate metrics against criterion devices (i.e. the Actigraph GT9X and Polar V800).

Method: 15 participants (Age 30 ± 4 years: 5 civilian and 10 military) were recruited for the study. The military population were all male (Mean height 185.9 cm ± 5.0; weight 94.2 kg ± 8.3). Civilians wore both commercially available wearable devices (i.e., WHOOP 2.0 and Apple series 3) and both the criterion devices; while soldiers wore one of the wearable devices (i.e., either WHOOP or Apple) and the criterion devices. Therefore, for each metric examined, 10 participants per device (5 civilians and 5 soldiers) provided data against the criterion devices. Data points available for comparison on each metric ranged from 15 to 54. Bland–Altman plots showing absolute error for each metric were created, and the mean bias and corresponding ninety-five percent confidence limits were determined. Pearson's correlations were calculated.

Results: The mean bias for sleep duration was smaller for the WHOOP (1 min) than the Apple (34 min), compared to the criterion. The WHOOP also had a small mean bias (-0.6%) for sleep efficiency. The Apple appeared to be more accurate at measuring metrics associated with physical activity; the mean bias for distance covered during training sessions was smaller for the Apple (51m) than for the WHOOP (133m; Noting that the WHOOP draws GPS data from the paired mobile device). Both devices seemed to adequately capture HR during exercise, with a small mean bias recorded for both WHOOP (0 beats·min^{-1}) and the Apple (-2 beats·min^{-1}) devices. For HR measured during sleep, small mean biases were also recorded for the WHOOP (-4 beats·min^{-1}) and Apple watch (-2 beats·min^{-1}). The WHOOP tended to overestimate HR variability during sleep (mean bias, 25 ms).

Conclusions: Decisions around which wearable device is more appropriate for the end user need to be grounded in a clear understanding of why the data is being captured, and what it is going to be used for. This can then inform the decision-making process to prioritise the metrics needed. Other design features such as the robustness of the device, and compatibility with a team-style dashboard or interface may also be important. Both the Apple and the Whoop appear to be sensitive in tracking relative change in physical activity and sleep metrics for the monitoring of soldier status.

The health and performance consequences of Australian Special Forces Selection and training courses (proposed research)

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Background: Military training, such as the Australian Special Forces Selection Course (SF-SC) involves high rates of energy expenditure coupled with additional stressors such as limited food, minimal sleep, and high cognitive demands. Whilst energy expenditures can vary significantly by job role and training requirements, it is not uncommon for soldiers to be exposed to negative energy balance, especially during field training. International research has demonstrated significant consequences of arduous military training, such as hormonal disruption and losses of lean body mass, strength, power and aerobic capacity. Full recovery from such training may take between three days to more than six weeks. The three-week SF-SC is considered to be one of the most arduous courses in the Australian military. A study conducted 25 years ago reported average daily energy expenditures of over 30MJ/day, while more recent records indicate an average weight loss of 18% body mass throughout the three week course. Despite the apparent extreme energy deficit incurred during this course, no known research has investigated the metabolic or physical performance consequences of, or recovery following, the SF-SC. Furthermore, no research has investigated the metabolic or performance consequences of the subsequent 18 month SF training cycle which follows the SF-SC.

Aim: The central aim of this study is to investigate the metabolic cost associated with the SF-SC, the physiological and performance consequences of the course, and recovery over the eight weeks following the course. Additionally, this study will conduct a longitudinal assessment of metabolic and performance measures throughout the subsequent 18 month reinforcement training cycle.
The central hypothesis is that the Special Forces Selection Course (SF-SC) will result in detrimental impacts to metabolic health and performance, and that recovery will be interrupted by subsequent training throughout the Reinforcement Training Cycle.

Methods: Part one of the study will involve before, after, and 8-week recovery period measures of body composition, hormones, resting metabolic rate and physical performance of soldiers attempting the SF-SC. Techniques utilised will include Dual X-ray Absorptiometry and Bioimpedance Spectroscopy (body composition), Indirect Calorimetry (resting metabolic rate), blood draws (hormonal analysis), Isometric mid-thigh pull on double force plates, countermovement jump on portable force plate, and 20m shuttle run (performance measures.) In addition, Doubly Labelled Water will be utilised to assess average total daily energy expenditure throughout each phase of the course, and energy intake will be assessed to allow an estimate of energy. Part two of the study will periodically observe the pattern of recovery of body composition, hormones, resting metabolic rate and performance throughout the 18 month Reinforcement Training Cycle following the SF-SC.

Exploring Simulated Submarine Motion and Sleeping Berth Orientation on Sleep

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Background: There is little objective evidence that shows whether motion and sleeping berth orientation in a submarine (an important consideration for design) impacts sleep amount and quality. Several studies undertaken on surface ships have found that motion negatively impacts sleep quality, however, none have examined the orientation of sleeping berths. Despite a lack of objective evidence, current recommendations for both surface ships and submarines in Australia and overseas state sleeping berths should primarily be longitudinally oriented.

Aim: This study aimed to determine the impact of an athwartships (transverse) berth orientation vs a fore and aft (longitudinal) orientation on sleep quality and quantity, and cognitive performance by simulating the *direction* of motion experienced at sea.

Method: 21 young healthy participants (13M/8F; aged 24.0±4.8 years; BMI 21.1±2.5) slept overnight in simulated submarine sleeping berths, on three occasions separated by a week of sleep at home. Sleeping berths were mounted on a motion platform (CKAS W7), which allowed for 6-degrees of freedom movement. Vessel motion patterns were replicated to simulate bunk orientation. In a repeated measures design, each participant slept under three conditions in randomised order; 1) no motion, 2) fore and aft orientation simulation (primarily side to side motion), and 3) athwartships or transverse orientation simulation (primarily head to foot motion). Sleep was recorded using ambulatory polysomnography (Compumedics Somte PSG). Participants completed pre- and post- sleep subjective sleepiness measures (Karolinska Sleepiness Scale; KSS), vigilant attention (Psychomotor Vigilance Task; PVT), and a post-sleep sleep-quality questionnaire. Data was analysed using Mixed Effects Analysis of Variance (ANOVA), controlling for order and including a random effect of subject ID on the intercept (to appropriately account for within- and between-subjects variance).

Results: Participants' total sleep time was shorter ($p<0.001$), their sleep efficiency was reduced ($p<0.001$), they woke more frequently ($p<0.001$), and their sleep contained less REM (dreaming) sleep ($p<0.001$) for the athwartships (transverse) orientation compared to the no motion and fore and aft orientation conditions. Participants' also reported significantly higher sleepiness on KSS ($p=0.006$), poorer subjective sleep quality ($p<0.001$), and displayed worse vigilant attention on PVT ($p=0.03$) following the athwartships (transverse) orientation compared to the other two conditions.

Conclusions: The athwartships berth orientation (transverse head-to-foot motion) negatively impacted sleep and cognitive performance. The long-term impacts are unknown as this study only measured participants for one evening in each condition with one test of cognitive performance. Additionally, this study exposed participants to motion throughout the whole night whereas submariners may only be exposed to these motions for short periods. Finally, participants were from the general population, whereas submariners may develop a tolerance to boat movements. It is recommended that future work collect data in submarine environments, over multiple nights, to examine sleep and sleeping berth orientation in real world settings, as well as studying older individuals, and people with a higher BMI or possible sleep disorder. Research Agreement Number: 9275

Session 2 – Biomechanics & Load Carriage

Monitoring Mechanical Load in a Military Population using a single IMU

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Background: Hard training for soldiers in high-performing elements is integral for physical and tactical enhancement, but also increases injury risk due to the greater mechanical load exposure. While it is possible to calculate the mechanical load encountered during Physical Training Instructor (PTI) directed physical training (strength and conditioning sessions), there is currently no way to quantify the mechanical load encountered during other occupational role-specific training (field work, weapons drills etc.).

Inertial Movement Units (IMUs) are electronic sensor devices that are capable of quantifying human biomechanics and mechanical load using accelerometer, gyroscope and magnetometer outputs. IMUs capture data that may be used to detect changes in movement patterns, which may indicate fatigue and injury risk, however, to accurately utilise IMUs, population-specific algorithms need to be developed. Following success in this area with national and international sporting codes, Athletic Data Innovations (ADI) were contracted to develop a military-specific mechanical load model 'proof of concept'.

Aim: The objective of this project was to develop a military-specific mechanical load model, utilising a combination of artificial intelligence, machine learning and threshold-based algorithms to identify a range of movements from key physical tasks to complex tactical movement patterns.

Method: Participants wore a single IMU (IMeasureU 'Blue Trident', 9.5g, 12-hour battery) attached via a prototype, soft textile waist belt with a secure buckle. Movement classification data was initially collected on seven non-military participants who performed an array of exercises typical to military training in various environments. Following development of a data pipeline, filtering framework, additional calculated columns and detection algorithms, exercises were performed by soldiers with a PTI taking participants through each discrete movement, whilst the IMU data was timestamped to accurately capture each exercise.
The data was used as training data. Models correctly detected whether a movement was ambulatory (92.9%), exercise class (97%), exercise category (94.2%), exercise name (96.8%) as well as making repetition counts.
Whilst still under development, the models showed acceptable performance to warranted data capture in increasingly complex, real-world settings. Data was therefore captured from more complex activities including urban operations training with plans to capture further military-specific data in the coming months.

Future Plans: Ongoing development over the next six months will be aimed at improving detection of all models using real-world data capture, whilst developing insights from the analysis alongside other physical test data from the subjects. The project has the potential to yield a mechanical load monitoring tool that quantifies military training and supports physical development of soldiers, may be used to measure and understand the mechanical load of various military activities and courses, as well as forming the basis of a load monitoring system that may assist in injury risk mitigation and career longevity for other military personnel.

The use of wearable technology in the evaluation of gait patterns of soldiers during weighted locomotion

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Background: There is a high volume of musculoskeletal injuries to military personnel whilst on a deployment, tactical hostile environment (Kollock, Lyons, Sanders, & Hale, 2019). It has been observed that 33% of these injuries were related either to lower back pain or non-contact knee injuries (Kollock et al., 2019). Army personnel work within one of three different states of weight loads. These weight loads are often determined by the task required of them for example, a patrol order can start at approximately 10 kg, a fighting order consists of approximately holding loads of 30 kg and a marching order can hold up to 50 kg (Pope, 2002). As such, Pope (2002) provides additional insight into the history over the past decade and found that loads carried by soldiers has been increasing over this duration. Consequently, this is leading to an increase in biomechanical changes within the gait cycle and that may increase the incidence of injuries.

Aim: The aim of this project will be to assess inertial sensors ability to identify changes in gait biomechanics in Australian Army solider during tactical movement. Through the utilisation of wearable technology which are compact and can potentially detect alterations in gait biomechanics.

Method: The current study is observational work in progress and will involve Australian Army soldiers that are medically fit will observed performing weight loaded walk. Initially base line of individuals gait pattern and comparing the three different states of external load and the biomechanical alterations. Participants will undertake their usual requirements of moving in either patrol (15 kg), fighting (25 kg) or marching (40 kg) order whilst wearing an inertial sensor on the lower back. Testing will occur weighted and unweighted. The motions to be assessed will be straight line activities. The kinematic measures will likely include cadence (stride time), trunk incline, and data magnitude e.g. acceleration. These measures will be observed for changes.

Results: This research is in the data collection stage but will be of interest to those within the military as their soldiers are their greatest asset ensure minimal injury are sustained will greatly advance their capability as a Defence Force.

Conclusions: The fitness requirement for tactical athletes encompassing often bears a resemblance to those of an elite athlete, there is a significant difference between their environments where tactical athletes are often exposed to highly unpredictable environment (Kollock et al., 2019). If a musculoskeletal injury is sustained during a hostile hazard whilst wearing any degree of external load, this could severely impact not only the individual but those that may have to attempt a rescue mission. Therefore, specific methods should be developed for those who work hard to protect and serve to minimise the risk of significant injuries.

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Are there kinematic sex differences across the gait cycle during overground load Carriage?

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Background: Load carriage is a universal soldiering task. Walking mechanics during load carriage are often studied to infer task performance and minimise injury risk (Seay, 2015). Given the removal of gender restrictions on combat roles within numerous armed forces (O'Leary et al., 2020), research investigating the differences in walking mechanics between males and females is increasing (Krupenevich et al., 2015; Vickery-Howe et al., 2020). However, these have generally been limited to comparing peak joint angles between sexes.

Aim: Investigate the interaction between sex and load on lower limb kinematics across the gait cycle during overground load carriage.

Method: Fifteen male (age: 22.3 ± 2.3 y, body mass: 74.2 ± 8.5 kg) and fifteen female (age: 25.1 ± 6.1 y, body mass: 61.5 ± 6.9 kg) load carriage naïve participants completed overground load carriage at three incremental external loads (0%, 20% and 40% of body mass (BM)) at a self-selected walking speed wearing runners. A Vicon motion capture system was used to track marker trajectories and a lower-body direct kinematic model used to calculate sagittal plane joint kinematics of the hip, knee, and ankle. Kinematics were time normalised to the gait cycle (GC) (0-100%). Repeated measures analyses of variance ($\alpha = 0.01$) using statistical parametric mapping (SPM1D; Pataky, Robinson & Vanrenterghem, 2013) were conducted to assess the interaction between sex and load across the GC. Where significant interactions or main effects were present, SPM1D two-tailed paired t-tests were conducted to determine the location of differences.

Results: There were no significant interactions or sex differences for any kinematic variable ($p>0.01$), however the effect of load was significant for all kinematics ($p<0.01$). Hip flexion increased as load increased for 0-20% BM from 89-100% GC ($t=3.799$, $p=0.002$) and 0-40% BM from 20-31% GC ($t=3.769$, $p=0.0026$). Knee flexion decreased as load increased for 0-20% BM from 46-61% GC ($t=4.0044$, $p<0.001$), 20-40% BM from 48-62% GC ($t=3.97$, $p<0.001$) and 0-40% BM from 46-64% GC ($t=3.936$, $p<0.001$). Knee flexion increased as load increased for 0-20% BM from 70-79% GC ($t=4.044$, $p<0.001$) and 0-40% BM from 93-100% GC ($t=3.936$, $p=0.002$). Ankle dorsiflexion increased (and subsequent plantarflexion decreased) as load increased for 0-20% BM from 50-61% GC ($t=3.988$, $p<0.001$) and 0-40% BM from 50-63% GC ($t=3.992$, $p<0.001$).

Conclusions: These results demonstrate that gait kinematics are similar across the gait cycle between men and women carrying loads up to 40% of body mass at self-selected walking speeds. Hip flexion (0-40% BM) increases during mid-stance, presumably to assist with the absorption of ground reaction forces; whereas hip (0-20% BM) and knee (0-40% BM) flexion increase during terminal-swing in preparation for heel strike, which may allow for more muscle activation upon heel strike to support the added load. Through pre-swing and toe-off, propulsion of the body as load increases may predominantly be controlled by the knee musculature (increased extension) rather than the ankle (decreased plantarflexion). The increase in joint flexion angles around heel strike and extended knee leading up to toe off will likely result in increased muscle activation and physiological demand.

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Impact absorption analysis during the gait wearing two military boots with and without load

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Background: Military boots are mandatory footwear in most military activities, including physical training, operational tasks and load carriage. The association between military tasks and the likelihood of developing musculoskeletal injuries in the lower limbs is widely recognized (Arndt et al., 2003). Military boots' midsole is often produced using styrene-butadiene rubber (SBR) or polyurethane (PU). In a previous study (Muniz and Bini, 2017), SBR midsole boots presented reduced impact forces at heel-strike compared to PU foam. However, the influence of loading carriage during walking with different military boots has not been assessed.

Aim: This study aimed at comparing ground reaction forces (GRF) during gait whilst using two models of military boots, with and without load.

Method: Walking gait was assessed in 28-soldiers using a 10-m walkway with two force platforms (Bertec, USA) embedded in the centre of the walkway. Soldiers had (mean ±SD) 18.9 (±0.6) years of age, a body mass of 67.3 (±8.6) kg and stature of 1.70 (±0.10) m. Gait trials were performed in the Biomechanics Laboratory during one visit, where GRF data were collected under four randomized crossover trials, wearing two military boots (styrene-butadiene rubber midsole – SBR – 63 Shore A; and polyurethane midsole – PU – 48 Shore A); with and without a 15-kg backpack. Participants were instructed to walk in their preferred gait style at a target speed of 5 ± 0.5 km/h, controlled by two photocells (Alge-Timing, Spain). Vertical GRF from the right lower limb was normalized by body weight and time-normalized to 101 points representing 100% of the stance cycle. Traditional vertical GRF parameters used in footwear analysis (e.g., first and second peak force, instantaneous loading rate – VILR -, average loading rate – VALR - and median frequency) were calculated. For evaluating the effects of different boots and backpack load, GRF parameters were separately compared by two- way ANOVAs with repeated measures (i.e., footwear, SBR, and PU; and load - with and without backpack).

Results: GRF parameters were reduced for the SBR boot (i.e., VILR and median frequency, $p < 0.01$ and $p < 0.0001$, respectively). Loaded walking increased first and second peak forces ($p<0.01$ for both outcomes). No interaction effect was observed, indicating that GRF results were reduced for the SBR boo with load.

Conclusions: SBR boot midsole presented better impact absorption compared to PU, suggesting that rubber-based materials in the midsole may be more effective in cushioning external loads during walking. Loaded walking presented greater GRF, which can lead to greater musculoskeletal overload regardless of boot midsole. This result suggests that the SBR boot performed better than the PU boot, regardless of the load. Further research could investigate the use of hybrid materials to be utilised in manufacturing boots midsole (e.g., Ethylene-vinyl acetate-EVA and carbon fibre).

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Toward Optimal Selection of an Assistive Device to Minimise Risk of Injury and Enhancement of Performance

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Background:

Assistive devices are designed to improve human performance (e.g. reduction of metabolic cost) and mitigate the risk of injuries. Among passive assistive devices, knee braces are common in use since knee injuries are among the leading musculoskeletal (MSK) condition in military and sporting situations. It is challenging to evaluate every assistive device in the field thus complementary models are required. Further, previous models have overlooked the role of the knee brace and lower-limb interactions. Computational models quantify the role of the MSK system during movements in order to predict muscle activation and joint loading. Thus, we propose a combination of experimental and computational models in evaluating a knee brace and the interaction with the lower limbs. To evaluate this interaction, knee brace parameters are required, including but not limited to, its weight, size and ability to generate forces which depend on its stiffness and damping levels. The metabolic cost of human activities can provide information on the physiological performance of a task and joint moments quantify risk of injury. Therefore, this study will develop a hybrid (experimental and computational) model to investigate the role of knee brace parameters on performance and injury mitigation.

Aim:

The aim of this study was to simulate the knee brace and lower-limb interaction using computer-based modelling during walking. We used recorded human movement data and attached a virtual knee brace to the MSK system to assess the impact of knee brace stiffness on overall metabolic cost during walking. We hypothesise higher knee brace stiffness will result in a greater metabolic cost of walking.

Method:

A computer-based model of the human with a knee brace where the stiffness could be parametrically changed from 1 to 4 Nm/deg was developed. A single male participant (72 kg, 1.8 m) walked at 1.2 m/s. A muscle-driven computational model was developed in OpenSim with and without the passive knee brace. A mathematical model was used to predict metabolic cost of each muscle in the model with 92 lower-limb muscle fascicles during a single stride. Total metabolic cost was calculated as summation of each muscle's contribution. Using this model, the role of other parameters of the knee brace (e.g. damping) on performance measures can be studied, however, only the role of brace stiffness on metabolic cost and lower-limb joint moments was evaluated in this study.

Results:

The results showed that knee joint moment decreased between 10 to 40 N while the ankle and hip joint moments increased when the knee brace was worn at 4 Nm/deg. As knee brace stiffness was increased from 1 to 4 Nm/deg, metabolic cost elevated by 24%.

Conclusions:

A combined experimental and theoretical framework, as proposed in this research, can be used to quantify the interaction between a passive assistive device and human performance which was shown to modify lower-limb joint moments by wearing the brace. Such modelling approaches has the potential to provide richer detail on the effectiveness of an assistive device and accelerate the evaluation and selection process for military and civilian applications.

Muscle Activation Differences in Raising and Aiming of a Rifle

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Background: Defence Project Land 159 aims to replace the small-arms capability in the ADF. Historically, engineering requirements for previous weapons Projects focus on target effects and timings in static, supported shooting to differentiate between weapon-systems and ancillaries during acquisitions. These assessments have had limited considerations of the interaction between the human and the weapon-system design. To support Land 159, objective metrics are being investigated for use in conjunction with target effects and timings. One possible metric, muscle activation, has been shown to be correlated to aim-point fluctuations in shooters (Konttinen et al., 2000), which is a predictor of shot accuracy (Mononen et al., 2007).

Aim: The aim of this work is to quantify the differences in muscle activation during rifle raising and aiming to inform physical ergonomics metric development for Land 159.

Method: Fourteen right-handed male rifle users (age: 34.1 ± 6.9 years, height: 181.4 ± 8.4 cm, mass: 91.6 ± 12.9 kg) fired 60 shots from an M4 at their own pace. Muscle activation was collected from four bilateral locations using electromyography (EMG). The weapon was fitted with a Myomotion Inertial Measurement Unit (Noraxon USA) with accelerometer data used to mark the events of weapon raise, aim start and the shot. Using these events, data were extracted, analysed, and normalised to a maximal voluntary contraction. The mean EMG from each raise-aim (raising) and aim-shot (aiming) period over the 60 shots was averaged. Differences between raising and aiming EMG for each of the muscles were quantified using paired t-tests as well as effect sizes (Cohen's *d)*.

Results: On average, EMG in the left trapezius was significantly greater ($t(14) = -3.57$, $p=0.003$) for raising ($M=35.2\%$, $SD=0.15$) than aiming ($M=30.9\%$, $SD=0.12$) with a small-moderate effect size (d =-0.32). The left brachioradialis was also significantly greater ($t(14) = -3.403$, $p=0.004$) for raising ($M=12.6\%$, $SD=0.07$) compared to aiming ($M=9.9\%$, $SD=0.05$) with a moderate effect size ($d=-0.46$). Conversely, the right triceps was significantly greater ($t(5) = 3.14$, $p=0.026$) for aiming ($M=4.5\%$, $SD=0.03$) as compared to raising ($M=3.4\%$, $SD=0.03$) with a small-moderate effect size ($d=0.38$). The right latissimus was also significantly greater ($t(8) = 2.36$, $p=0.046$) for aiming ($M=9.3\%$, $SD=0.05$) as compared to raising ($M=8.5\%$, $SD=0.05$) with a small effect size ($d=0.17$).

Conclusions: There is little difference in EMG between weapon raising and aiming. The differences seen were side-dependent, i.e. raising was greater on the left side, while aiming was greater on the right side. Two of the left-sided muscles; the infraspinatus and deltoid, had large variation for both raising and aiming. This suggests that these muscles could be further investigated to understand inter- individual differences in movement patterns that may contribute to muscle fatigue and lower target accuracy.

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High-quality human motion measurement in the field using wearable sensors

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Introduction: Accurate measurement of defence personnel body motion (kinematics) in the field is critical for monitoring physical demands and responses of the body to optimise human performance. Joint angles are the clinically relevant and universally accepted measure to quantify inter-segment angles at a joint, and are widely regarded as the most important measure for interpreting joint function in human movement. Traditional approaches to measuring joint angles require use of high-speed video motion analysis cameras in a dedicated laboratory; however, this environment typically has a restricted capture volume and may not be representative of real-life in-field conditions. New developments in motion measurement technology include inertial measurement units (IMUs), which are lightweight, portable and wireless sensors that measure human motion in almost any environment. Unfortunately, IMUs provide limb-segment orientation estimates via integration of their outputs i.e., linear acceleration and angular velocity data, and accurate calculation of 3D joint angles remains an unsolved problem. The aim of this study is to employ advanced Deep Neural Networks (a branch of Machine Learning) to convert raw IMU data to joint angles during walking.

Methods: Nine healthy subjects were recruited and walked for 20 strides on a treadmill, while lower limb motion data were collected using a 10-camera video motion analysis system as well as three IMUs, one each mounted to the foot, shank and thigh. Using the video motion analysis system, trajectories of retro-reflective markers were converted to 'gold standard' joint angles using inverse kinematics. We then employed a Generative Adversarial Network (GAN) model to convert the raw low-quality IMU data to gold-standard video-motion analysis data. The model was trained and independently tested using a leave-one-out cross validation. RMS errors and paired t-tests were used to quantify differences in ankle joint angles between gold standard, IMU and GAN model measurements. Significance level was set at $p<0.05$.

Results: In comparison with gold-standard video motion analysis data, the IMUs and GAN model produced RMS errors at the ankle joint of 10.2deg and 2.7deg, respectively. The overall trends show close agreement between the GAN model and video motion analysis for ankle flexion, inversion and internal rotation measurements throughout the gait cycle. For example, at heel-off, there were significant differences in ankle dorsiflexion angle measured using IMUs compared to video motion analysis (mean difference: 6.0deg, $p<0.0001$), but no significant differences between GAN-model predictions and video motion analysis measurement (mean difference: 1.1deg, $p>0.05$). Similarly, at both heel-off and toe-off there were significant differences in ankle inversion and internal rotation between IMU measurements and video motion analysis ($p<0.001$), but no significant difference between GAN-model predictions and video motion analysis measurement ($p>0.05$).

Conclusions: The findings of this study show that Deep Neural Networks (Deep Learning) can be used to compute high quality joint angles, equivalent to video motion analysis measurements, using raw IMU data. The findings have significant potential for the use of wearable sensor technology for real-time human performance measurement of defence personnel in any location, including front-line combat. Future applications will employ larger cohorts for performance monitoring, assisted decision making and injury prevention.

A NECK LOAD MONITORING SYSTEM FOR HELMETED AIRCREW

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Background: Neck pain is an international concern for both fixed and rotary wing aircrew. Helmet design, helmet mounted masses, head checks, high Gz manoeuvres, sustained postures, platform vibration and long flights are all thought to contribute. More capable aircraft, more sophisticated helmet mounted masses will likely increase the problem. Measuring neck force magnitude, site and repetition is important for understanding both cause and mitigation of this widespread problem. Following success of load monitoring for reducing musculoskeletal injury in elite sports, we have developed a prototype neck force monitoring system for fast jet pilots. The same system could readily be deployed for rotary wing aircrew.

A system of systems: Passive Inertial Sensors- Integral to our monitoring system is a specialised inertial sensor. Due to the highly secure cockpit environment and the requirement for passive only sensors, our system is able discern head on trunk co-ordinates, relative to the airframe with accuracy within 1 degree.
Head position machine learner- through a series of studies and simulations we have been able to develop an algorithm that classifies with 96-100% accuracy each head movement or task, to calculate frequency of specific postures and time held.
Helmet modelling system- through an application of both computer simulation and 3-dimensional motion capture of typical aircrew tasks, we have the capacity to create neck load models for any helmet, if given the inertial properties of the helmet and associated configurations.
Neck Workload Modelling -by combining the helmet modelling system, the passive inertial sensor data and the head position machine learner we can calculate the neck force applied to aircrew throughout a flight or series of flights, down to the level of a single vertebra or muscle. When the system has been tested against lab based calculations error is minimal ($R2=0.994$, RMSE=1.129).

Conclusions: This system of systems is the only of its kind that can measure dynamic neck loads in aircrew. Load monitoring is vital in order to better understand and manage the risk of neck pain in aircrew.

Quadriceps muscle oxygenation may be used as a proxy for knee joint torque during load carriage: a pilot study

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Background: Load carriage is a common requirement for many military personnel. It is well- established that the addition of weight carried incrementally increases pulmonary oxygen uptake (Dominelli, Sheel, & Foster, 2012) and external joint torque (Jaworski, Jensen, Niederberger, Congalton, & Kelly, 2015). These changes reduce the time to fatigue and increase the risk of injury. However, measuring oxygen uptake at the mouth does not yield information regarding the oxygen consumption of individual muscle groups that work around a specific joint. In particular, external weight carried on the back places an additional work requirement on the leg muscles during walking (Al-Khabbaz, Shimada, & Hasegawa, 2008), thus presumably increasing their oxygen requirements. Although we hold the technology to test the oxygen status of multiple tissues in real-time (Ferrari, Muthalib, & Quaresima, 2011), it is not clear how load carriage effects leg muscle oxygenation and how that relates to joint torque. Direct measures of joint torque are difficult outside the laboratory setting. A wearable sensor system based on muscle oxygenation that can estimate joint torque has the potential to monitor this critical biomechanical parameter in context-specific conditions (in the natural environment).

Aim: To determine whether a correlation exists between quadriceps muscle oxygenation and knee joint torque during load carriage.

Method: One participant walked on an instrumented treadmill at 4km/h for 5min in six loading conditions: no weight, 16%, 24%, 32%, 40% and 48% body mass. Conditions were 5 minutes in duration and randomly presented. Kinematics (Vicon) and kinetics (AMTI) data were recorded to calculate knee moment. In order to quantify the physiological (muscle oxygenation) responses to load carriage while walking, a Near-infrared Spectroscopy (NIRS, Perrey & Ferrari, 2018) probe was attached to the vastus lateralis of the dominant leg (thigh) to measure oxygen content. The peak knee moment was computed using inverse dynamics algorithms for each step and averaged for the final minute of each trial. Muscle oxygenation was averaged for the final minute of each condition when the participant reached steady state. Pearson's correlations were performed to investigate the relationship between muscle oxygenation and knee external flexor moment. Correlations were considered statistically significant at the 0.05 level.

Results: There was a strong significant correlation between oxygenation of the vastus lateralis and maximum knee external flexor moment ($r = 0.90$; $R2 = 0.8085$; $p = 0.0147$), and the change in oxygenation of the vastus lateralis and the change in maximum knee external flexor moment ($r = 0.96$; $R2 = 0.9205$; $p = 0.0097$).

Conclusions: Oxygenation level recorded in real-time has the potential to be used as an indicator of joint load. A system of wearable NIRS sensors that are capable of quantifying joint load offers the benefits of being minimally invasive and lightweight and might be suitable for use in real-life contexts.

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Validation of a Machine Learning Algorithm to enhance decision making in the management of Medial Tibial Stress Syndrome

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Background: Medial Tibial Stress Syndrome (MTSS) has been identified as the most costly musculoskeletal injury (MSKI) to the British army (Sharma, Greeves et al. 2015), affecting 35-80% of military trainees. There is no reliable treatment for MTSS and reoccurrence rates are high. Prevention of MTSS is critical to reducing operational burden. Typically injury prediction is complex, multivariate, and has not been capable of discerning individual level risks.

Aim: This study investigated the accuracy of a machine learning approach that combines best known risk factors into an individual risk profiling tool for a common MSKI.

Method: Using a prospective design, this study collected a suite of key variables, determined in a previous study of navy recruits (Garnock, Witchalls et al. 2018), in a new population from the Australian Defence Force Academy. Data was obtained from 107 recruits (35 females and 75 males). Follow-up was conducted at 3 months to determine those in the group that had developed MTSS, when a total of 99 recruits (69 males, 30 females) remained for inclusion in statistical analysis. Six ensemble learning algorithms- Decision Tree, Support Vector Machine, Logistic Regression, K- Nearest Neighbour, Random Forest and Naïve Bayes were deployed and trained 5 times on random stratified samples of 75% of the dataset. The resultant algorithms were tested on the remaining 25% of the dataset and the models were compared for classification accuracy, precision and recall, and Predictive Lift. The most accurate new algorithm was additionally deployed on the previous dataset of navy recruits in order to further validate the accuracy of the model.

Results: Random Forest modelling was the most accurate with a classification accuracy of 92%, Area Under the Curve 98%, precision 91% and recall 92%. When this model was applied to an unrelated dataset it performed with similarly high classification accuracy of 93%, Area Under the Curve 93%, precision 93% and recall 93%. Lift curve analysis showed that treating the top 30% of at risk individuals would result in an 80% reduction in MTSS injuries.

Conclusions: This model is highly accurate in predicting those who will develop the debilitating condition of MTSS. The model provides important preventive capacity which should be trialled as an intervention.

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Musculoskeletal Injuries in the Australian Defence Force- "No Worries Mate!" ?

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Background: Does Australia have a problem with Musculoskeletal Injury (MSKI) in the Defence Force? What has changed over the last 20 years?

Method: A narrative review of US, UK and ADF MSKI injury reports over the last 20 years was undertaken and the findings synthesised.

Results: Musculoskeletal Injury (MSKI) is reportedly the most significant cost to military health services around the world. In 2018, 53% of the U.S. Army had sustained a new musculoskeletal injury (MSKI), resulting in over two million injury-related medical presentations, accounting for 59% of 4.1 million work-days-lost. Of these, 71% were overuse injuries, likely preventable. In the U.K. in 2018/2019 injury rates increased over the previous 5 years to be between 44 and 91 injuries/1000 personnel. These injuries accounted for 63% (n=13,896) of all Health and Safety incidents reported. Illnesses accounted for approximately 2% of all reports. These datasets were obtained from integrated sources including medical records, personnel records, and Health and Safety Reports. These countries are now leading the way in injury surveillance and prevention for military organisations.

In 2000 the Australian Defence Force (ADF) commissioned the Health Status Report, in which the lack of data and surveillance was identified as a key deficiency. As a direct consequence the Defence Injury Prevention Program was developed. This system captured 80-95% of all care-seeking injuries, and revealed an alarming injury rate in some units of up to 2100 injuries /1000 personnel. The priorities and countermeasures informed by this data contributed to injury reductions of up to 30% per year, and ran for 7 years. Since closure of the DIPP, no current similar system exists in the ADF.

The ADF has since spent $133 million on the Defence electronic Health System (DeHS). However the data required to produce the 2015 Physical Health Status report had to rely on a survey of defence members, to which only 17% of the serving ADF responded. Perhaps MSKI in the ADF is not really a big problem. Yet the 2019 Productivity Commission Inquiry into Veterans Compensation and Rehabilitation found DVA are spending $5.3bn per year on medical expenses.

Current focus and investment into cognitive performance optimisation, next generation technologies, better equipment, revised physical employment standards, and physical conditioning optimisation have all included an aim of reduced injury burden. However, where similar initiatives have been deployed in the US, the MSKI burden is not decreasing, it is merely diversifying injury types. Without surveillance evidence, force preservation efforts in the ADF can only be evaluated by anecdote.

Conclusion: Data from other countries indicates that 10-50% of ADF personnel will be injured each year. The ADF cannot currently quantify the MSKI impact nor evaluate the efficacy of Human Performance initiatives with sufficient fidelity. The current lack of direct injury surveillance within the ADF creates an inability to develop appropriate prevention, and reduces the ability to keep personnel "Fighting Fit".

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DHSS 2020 – Abstracts | Day 2

Session 3 – Cognitive Performance & Enhancement

Recovery of cognitive performance following multi-stressor military training

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Background: Military personnel are often required to work in challenging multi-stressor environments where sleep loss is inevitable. Despite the known decrements in cognitive performance following sustained military operations and simulated combat training in multi-stressor environments (Friedl et al. 2001; Lieberman et al. 2005; Lieberman et al. 2009), little is known about performance in missions lasting longer than 80 hr and the recovery time-course of cognitive performance post-operation. Understanding how fatigue resulting from continuous physical and mental exertion in these contexts can impair cognitive performance, and how performance recovers following military operations, can assist with operational risk management in minimising adverse performance outcomes.

Aim: The aims of this project were to 1) assess the impact of an eight-day military training exercise involving severe sleep restriction on cognitive performance and subjective responses to training demands, and 2) track the recovery of these variables in periods of reduced workload and partially restored sleep.

Method: A total of 57 male and female soldiers undergoing the Australian Army combat engineer Initial Employment Training course were recruited and tracked over a 16-day study period which included an eight-day field-based military training exercise. Cognitive performance (i.e. psychomotor speed, reaction time, visual tracking, working memory, vigilant attention, executive function) was assessed using a computerised test battery every two days. Subjective perceptions of load and fatigue were evaluated daily via questionnaire. Measures were collected across four sequential study periods;
1) baseline (PRE; days 1-4), 2) in the field which included one night of total sleep deprivation and sleep restriction for other nights [~3.5 hr/day; (EX-FIELD; days 5-8)], 3) at a simulated base with sleep restriction [~6 hr/day; (EX-BASE; days 9-12)], and 4) recovery (REC; days 13-15). Sleep duration was continuously measured via actigraphy, subjective sleep quantity and quality were also evaluated at day 0 and 15.

Results: Following the EX-FIELD period, cognitive performance in tasks assessing psychomotor speed, reaction time, visual tracking and vigilant attention were impaired by up to 15% ($P<0.05$). Most affected measures had recovered two nights following EX-FIELD (when a total of ~16.5 hr sleep had been achieved); at the end of EX-BASE there was no difference in the performance of these same tasks compared to PRE. Measures of vigilant attention were still impaired following the three-day recovery period which included 6.3 hr/day of sleep. The eight-day period of simulated operational activities was also associated with increased perceived exertion, fatigue and subjective load, which had not recovered by the end of REC.

Conclusions: The sensitivity of the cognitive tests to periods of sleep deprivation, sleep restriction, and recovery suggests they may be useful indicators of soldier readiness; however, decision thresholds would need to accommodate inter-individual differences. Despite the apparent recovery of most cognitive performance indicators, subjective data indicated that additional recovery time may be required before re-deployment or further exercises. Perceptual factors may therefore need to be considered in personnel management decisions. Studies should continue to explore other indicators operational readiness in military personnel, and avenues that preserve within-exercise vigilance and accelerate perceptions of recovery

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Transcranial direct current stimulation of prefrontal cortex augments multi-session single/dual-task training and induces near transfer: A dosage study

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Background: Transcranial direct current stimulation (tDCS) has been shown to improve single- and dual-task performance in healthy participants and enhance transferable training gains following multiple sessions of combined stimulation and task-practice. However, it has yet to be determined what the optimal stimulation dose is for facilitating such training outcomes.

Aims: To test the effects of different tDCS intensities with a commonly used electrode montage on performance outcomes in a multisession single/dual-task training and transfer paradigm.

Methods: In a pre-registered study, 123 participants, who were pseudorandomised across four groups, each completed six sessions (pre- and post-training sessions and four combined tDCS and training sessions) and received 20 minutes of prefrontal anodal tDCS at 0.7 mA, 1.0 mA, or 2.0 mA, or 15 second sham stimulation. Response time and accuracy were assessed in trained and untrained tasks.

Results: We observed significant improvements in the single and dual-task reaction times and dual-task accuracy for 1.0 mA when compared to sham performance. The 1.0 mA group also showed near transfer to an untrained single/dual-task. The 0.7 mA protocol only improved single-task response times relative to sham, with no effects on dual-task performance or transfer.

Conclusion: Training performance gains are augmented by tDCS, but their magnitude and nature are dependent on the stimulation intensity. Specifically, only a mid-intensity stimulation condition (1.0 mA) led to both improvements in performance (both reaction time and accuracy) and near transfer to an untrained task.

Acknowledgements: This research was also supported by an Australian Research Council (ARC) Discovery grant (DP140100266, PED & JBM), the ARC-SRI Science of Learning Research Centre (SR120300015, PED & JBM), and the ARC Centre of Excellence for Integrative Brain Function (ARC Centre Grant CE140100007, JBM). JBM was supported by an ARC Australian Laureate Fellowship (FL110100103), HLF by a UQ Fellowship (UQFEL1607881) and an ARC Discovery Early Career Researcher Award (DE190100299).
SE & YW acknowledge support through the Australian Government Research Training Program Scholarship

Cognition research in the cyber domain: a scoping review

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Background: The Australian Government recently acknowledged that the nation's strategic environment has been complicated by faster-than-expected expansion of cyber capabilities amongst the region's state and non-state actors. In response, they have committed to significant investment in cyber capability for the Australian Defence Force (ADF) (Australian Government Department of Defence, 2020). Research and investment in the cyber domain have traditionally emphasised development of technological approaches and tools, while overlooking the human element. Although numerous technologies have been developed for cyber offence (e.g., malware, denial-of-service) and defence (e.g., intrusion detection, firewalls), cyber operations remain heavily human in-the-loop processes. Humans' cognitive processes are fundamental to successful cyber-attack (e.g., planning, vulnerability recognition, deception) and cyber-defence (e.g., network situational awareness, data sense-making, timely decision-making to outsmart attackers). While a preliminary scan of the literature by the author identified a small number of reviews that examined a specific area of cognition-cyber research in detail (e.g., cyber situation awareness; Gutzwiller, 2019), there has been no overarching review and synthesis of the full breadth of human cognitive research in the cyber domain.

Aim: The aim of this scoping review is to identify and characterise the literature examining the cognitive aspects of performance amongst professionals working in the cyber domain. The review will help establish aspects of cognition that have been researched, methods and measures employed, efforts to enhance cyber professionals' cognition, and key research contributors, as well as uncover knowledge gaps in this area. This will potentially inform subsequent research activities and literature reviews.

Method: The review is following the methodological framework of Arksey and O'Malley (2005): identifying the research question; searching for relevant studies; selecting studies; extracting the data; and collating, summarising, and reporting the results. Searches for literature are being conducted on applicable bibliographic databases including, but not limited to, Scopus, IEEEXplore, ACM Digital, and PsycARTICLES. The review will only include cyber professionals (i.e., individuals working specifically in cyber security, defence, and operations), and will exclude other cyber-related populations (e.g., company employees falling for phishing emails).

Results: This review is currently in its early stages of progress. It is anticipated that it will report preliminary findings on methodologies used to explore cyber professionals' cognition, interventions that may show potential for enhancing their cognition and performance, areas of the cyber domain where cognitive enhancement may have greatest application, evidence gaps warranting further investigation, and the barriers that might arise when conducting human research in this technocentric (and often highly-classified) domain.

Conclusions: Despite the technocentric nature of the cyber domain, the human element remains a fundamental input into successful cyber operations. Any significant investment in developing organisational cyber capabilities, such as that recently announced for the ADF, would be remiss not to consider and incorporate measures to enhance the performance of human operators. One approach is to evaluate and develop the cognition of cyber professionals, thus potentially improving their capacity

to manage the complexity of the domain. This scoping review will ideally provide an overview of existing research in this area, and a starting point for future work.

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The impact of sleep loss on performance monitoring and error-monitoring: A systematic review and meta-analysis

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Background

Many individuals such as shift workers, first responders, and military personnel are required to function on limited sleep, and consequently, are at risk of making errors due to sleepiness. Awareness of performance deficits and errors (performance monitoring and error- monitoring) is therefore critical in preventing the consequences of sleep loss and may potentially be a key feature of elite cognitive performance (Aidman, 2020). However, it is unclear whether sleep deprived individuals have insight into their performance.

Method

We conducted a systematic review and meta-analysis of the impact of sleep loss (<6 hours sleep) on monitoring of performance and errors using Embase, MEDLINE, PsycINFO & Cochrane Central.

Results & Conclusions

We identified 28 studies, 11 of which were appropriate for meta-analysis. We identified three questions were addressed by the performance monitoring literature; 1) Does sleep loss influence performance monitoring accuracy?; 2) What is the relationship between objective performance and subjective ratings of performance during sleep loss?, and; 3) What is the impact of sleep loss on the relationship between performance and confidence? We found the impact of sleep loss on performance monitoring varied depending upon the method used to measure performance monitoring. The accuracy of self-assessed performance differed under sleep loss conditions, however on tasks where sleep loss significantly affected participants' ability to accurately monitor their performance, participants demonstrated more conservative estimates of performance. Confidence-accuracy relationships did not appear to be influenced by sleep loss and no consensus could be reached regarding the impact of sleep loss on objective performance and subjective accuracy ratings, due to inconsistent methodology. The error-monitoring literature was more consistent, with a consensus suggesting sleep loss impairs both unconscious error-detection and conscious error-awareness processes.

Additionally, this review highlighted two important methodological limitations of current research: 1) the influence of bias within metacognitive measures, and; 2) the lack of behavioural methods in error-monitoring studies to substantiate changes observed in electrophysiological measures. Therefore, future research must employ improved methodological and statistical measures. Specifically, performance monitoring research should leverage the methods developed by psychophysicists in the framework of Signal Detection Theory and implement bias-free measures of metacognition such as the meta-*d'*. Error monitoring research should collect behavioural reports about participants' awareness of their errors in parallel with electrophysiological measures such as electroencephalography.

These additions will enable more definitive conclusions to be made on how performance monitoring and error-monitoring are influenced by sleep loss. Such research could identify the neural mechanisms decreasing or preserving performance and error monitoring and has implications in the development of fatigue management strategies which may reduce the dangerous consequences of sleep loss.

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Identifying Neurobiological Markers of High Performance on an Undersea - Decision-Making Task

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Background

During undersea decision making, individuals are required to integrate multiple sources of – often uncertain – information varying in spatiotemporal complexity. This information is used to make rapid decisions within dynamic environments, a process that is underpinned by effective team communication and a range of cognitive mechanisms that likely differ among individuals. While research has started to understand the macro-level factors (e.g., teamwork dynamics), it is virtually unknown whether individual differences in neurobiology predict undersea-relevant cognitive performance and decision-making.

Aim

The aim of this ongoing project is to examine neurobiological markers of cognitive capabilities and learning potential for undersea decision-making tasks. It examines whether electroencephalographic (EEG-based) markers of individual differences in information processing (e.g. individual alpha frequency [IAF]) modulate inter-individual differences in performance on a complex undersea decision-making task.

Method

Sixteen participants (9 female; mean age = 24.4, SD = 5.1) have been tested to date. We used a single-operator Target Motion Analysis component of the control-room-use-simulation environment (CRUSE). It involved integrating information from various different sources to plot a “solution” for each contact in the environment, i.e. a model of the contact’s range, course, speed and bearing. Performance was quantified using tactical picture error (TPE), the difference between the solutions plotted for all contacts and the simulation ground truth weighted by the priority of each contact. Prior to undertaking the CRUSE task, participants completed a training session, the Big Five Personality inventory, and a range of psychometric inventories and cognitive tasks (e.g., mental rotation and statistical learning tasks [SLT]). IAF was estimated from occipital-parietal electrodes during resting- state eyes closed.

Preliminary Results

There was a strong positive correlation between polychronicity – a construct indicating a preference for multitasking – and CRUSE self-efficacy post-training – a measure reflecting participan elf-assessment of their ability to complete the CRUSE task (r = .51, p <.05, 95% CI = [.04, .85]).

Mixed-effects modelling for TPE revealed interactions of IAF x Time (Type II Wald test: $\chi2(1) = 11.16$, $p < .001$), SLT x Time ($\chi2(1) = 46.49$, $p < .001$) as well as a marginal interaction of IAF x SLT x Time ($\chi2(1) = 3.84$, $p = .05$), indicating that TPE decreased over time, and that a high statistical learning ability and high IAF predicted a steeper slope of this decrease. Differences in SLT were particularly apparent for low-IAF participants.

This suggests that higher performance on the SLT and a higher IAF estimate is associated with improved performance on CRUSE over time. However, the impact of SLT is reduced for individuals with a high IAF.

Conclusions

Preliminary analyses indicate complex associations between behavioural, psychometric and neurobiological markers of information processing with CRUSE performance. We plan to have collected data on the full sample size of n=40 by the conference, enabling us to report more conclusively on the interactions between factors of interest. We expect that these results will offer novel insights into the mechanisms underlying individual performance and the suitability of candidates for particular roles relevant to undersea decision making.

Enhancing Sensemaking: Supporting Distributed Groups in the Future Operating Environment

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Overview:

The Future Operating Environment (FOE) is likely to place additional cognitive demand onto Command and Control (C2) teams due to increases in technology, a wider range of potential threats and the expansion of battlespace domains to include cyber and space. In addition, due to technology and threat advances, distribution of people, artefacts, time and functions is likely to increase in the future making sensemaking more challenging. This paper asks the question: "How can distributed sensemaking research enhance military outcomes in the Future Operating Environment?"

Background:

Sensemaking is the cognitive function and associated cognitive processes used to determine when an unfolding situation may not be as originally perceived. Sensemaking can support the interpretation of complex, dynamic, multifaceted situations and involves both recognising that a routine situation is moving to non-routine and also deciding how much of the information load can be ignored. Sensemaking is a process that can be distributed across:

- different people and the things they use to record or process information;
- time, so that we might recall previous experiences of relevance or make predictions of future situations;
- functions, so the perspective of one sensemaking agent might conflict with that of another.

Aim:

The overall aim of our ongoing research programme is to derive a set of principles that can be used to guide the design and assessment of distributed sensemaking environments. If we see sensemaking as distributed then we require approaches which can measure and change the ways in which military personnel gather and process information (training), the ways in which they understand information and how to interpret it (culture), the ways in which information is shared and interpreted (processes), and the ways in which information sharing is supported (technology). Distributed sensemaking is critical in support of coordinated actions by disparate units of action.

Findings:

The following definitions are put forward:

Distributed sensemaking unit (DSM unit): An individual, a semi-autonomous or autonomous system, or a collaborating group (of DSM units) who perform a sensemaking function.

Distributed sensemaking (DSM): a process through which one or more DSM units seek to explain, understand, or otherwise make sense of a situation under uncertain or ambiguous conditions for informing a course of action. During DSM, each DSM unit seeks data and applies its values and goals, expertise and domain knowledge to synthesise data, draw inferences and share situation- pictures with other DSM units for collective understanding and co-ordinated action. As a sensemaking agent, each unit imposes a particular 'view' of what information is important (and which can exclude information that does not conform to its ways of interpreting or representing information).
Nine principles for distributed sensemaking are put forward. The principles relate to information interaction and collaborative interpretation with implications for training, ways of working and the design and provision of technology.

Conclusions:

The next steps for experimental research to test these findings will be outlined in this presentation.

Visualisation and Quantification of Gaze-strategies in a Dynamic Environment

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Background: Gaze strategies are greatly valued in safety-critical environments (Hauland, 2008). In the context of military training, investigating the relationship between performance and gaze strategies provides valuable insights into training processes. Studies related to gaze strategies detection have mostly employed static references (example: images or equipment's) (Anderson, Bischof, Laidlaw, Risko, & Kingstone, 2013; Hauland, 2008). However, considering the dynamics of complex operations and learning capabilities of individuals, some gaze strategies may be better suited to the task dynamics than others, leading to enhanced performance.

Aim: In the context of dynamic environment, to demonstrate epistemic network analysis (ENA) as a gaze-strategy visualisation tool, and to explore whether effective visual strategies can be quantitatively identified using cross recurrence quantification analysis (CRQA).

Method: 25 participants completed 10 trials of a UAV-refuelling computer simulation task. Gaze of the participants were collected using a desktop mounted eye-tracking device. Categorical gaze time- series was constructed for every trial, such that at any time the gaze of the participant represented one of seven areas of interests (AOIs): 5-UAVs, simulation's timer and background. To eliminate biases from training and experience development, only data from last 5 trials were chosen in the analysis (Brockmole, Hambrick, Windisch, & Henderson, 2008; Newell & Rosenbloom, 1981). Four performance groups (excellent, above-average, below-average and poor) were derived based on performance score distribution of the participants.

Every trial progression was analysed using the following methods:

1. ENA was employed to observe gaze strategies based on the spatial distribution of gaze on the AOIs.
2. CRQA was employed to quantify the amount of gaze recurrence on each AOI. Thus, every trial is represented with a vector comprising of relative gaze-recurrence (%) from 7 AOIs.

In accordance with *information-reduction* hypothesis (Haider & Frensch, 1999), a composite index (I_{diff}) representing the strength of strategy was derived for every trial based on the difference between maximum recurrence to median.

Results: From ENA, three distinctive gaze strategies were visually identified as: dominantly fixating on one UAV (UAV-bound), dominant fixations on timer (timer-bound) and fixations distributed on UAV and timer (UAV_timer-bound). The UAV-bound and timer-bound strategies showed significant associations with higher performance scores and were observed within the excellent and the above- average performing groups. Pearson's correlation analysis indicated a strong positive correlation between I_{diff} , and the performance scores. Further, I_{diff} of all the performance groups were significantly different, except between below-average and inferior groups.

Conclusions: The identified strategies could be directly linked to task dynamics (fuel cycle of UAVs). Results indicate the presence of multiple strategies, however, UAV-bound and timer-bound were observed to be better than the others. The gaze-recurrence addressed fixation count and longer fixations, and I_{diff} provided better representation of selective-attention, covering multiple gaze theories comprehensively relating to performance. The findings also support the evidence to employ I_{diff} as an objective performance measure. Potential applications include monitoring and assessment of operator performance that would allow observation and visualisation of an operator's strategic distribution of gaze in near-real-time.

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Multi-modal Cognitive Training with an Immersive Virtual Reality Marksmanship Task and Mindfulness Mediation

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Background: There is growing interest in cognitive training approaches to enhance the cognitive substrates of performance in complex environments. While there is evidence to support the efficacy of cognitive training interventions for enhancing performance on untrained tasks (Jaeggi et al., 2008), some (e.g., Schwaighofer et al., 2015; Klingberg, 2010) have questioned the extent to which cognitive training derived benefits are generalisable. The lack of generalisable benefits from cognitive training might stem from the tendency for these interventions to train a singular cognitive modality – attention or working memory, for example – while complex task performance relies on integrated functions of several cognitive processes. Cognitive training interventions that incorporate several cognitive modalities in distinct situations and environments might better afford gains in cognitive capacity (Sala & Gobet, 2017; Sprenger et al., 2013).

Aim: Our aim was to test the efficacy of a novel, multi-modal cognitive training intervention for enhancing attention and working memory. One element of the intervention was based on a marksmanship task that was immersed in virtual reality (VR). We developed the VR marksmanship task to incorporate several cognitive modalities including selective attention, response inhibition, and working memory load. The second element of the intervention involved mindfulness meditation training via an audio-guided technique we developed based empirical evidence that meditation states engage cognitive processes and neural systems associated with regulation of executive function (Tang, Hölzel & Posner, 2015). We tested the extent to which attention and working memory function could be enhanced by integrating mindfulness meditation training with VR marksmanship training in comparison to training with VR marksmanship alone.

Method: Forty-five right-handed, meditation naïve civilian participants (age 22.67 ± 3.85 years, 23 females) were recruited and completed all aspects of the study in a laboratory setting over a 1-week period. Participants were randomly allocated to one of two cognitive training condition groups: VR marksmanship and mindfulness mediation cognitive training; or VR marksmanship training alone. Both groups completed VR marksmanship training across six sessions while participants who also received mindfulness meditation training completed four sessions of the audio-guided technique. Before and after cognitive training, attention function was tested using the attention network test (Fan et al., 2005) and working memory was tested using a digit span task (Richardson, 2007).

Results: Working memory capacity significantly improved following joint VR marksmanship and mindfulness meditation training but did not significantly improve following training with the VR marksmanship task alone. No statistically significant improvements for attention function were observed following VR marksmanship training, with or without the addition of mindfulness meditation training.

Conclusions: The results illustrate the advantage of integrating mindfulness meditation training with VR marksmanship training for the enhancement of working memory capacity. A higher volume of cognitive training with the marksmanship and meditation training might be necessary in order to elicit enhancement of attention function. Overall, the present findings are consistent with the principle that generalisable enhancement of performance from cognitive training relies of interventions that expose individuals to training involving multiple cognitive modalities and settings.

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Genetic Markers of Cognitive Fitness

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Background: To function effectively, warfighters must maintain high levels of cognitive performance, particularly in high-risk, cognitively demanding roles. Understanding the genomic architecture and molecular mechanisms of cognitive functioning in healthy individuals is critical to developing effective training programs to enhance cognitive fitness (Aidman 2020). There has been substantial progress in uncovering the genetic composition of the general cognitive ability (*g*). Less is known about executive functioning (EF) – another key predictor of cognitive fitness, distinct from the *g* factor. While it is well established that *g* and EF overlap at the phenotype level, little is known about the underlying biology of this relationship.

Aim: We aimed to map the genetic architectures of *g* and EF by systematically reviewing existing literature that utilised a gold-standard genome-wide association study (GWAS) methodology. A GWAS maps single nucleotide polymorphisms (SNPs), which are variations in single DNA building blocks (nucleotides) within genes, that are associated with specific biological or behavioural phenotypes. Given a well-known overlap between g and EF at the phenotype level, we hypothesised that there is an overlap as well as distinction in underlying molecular biology for *g* and EF, which can be identified using existing GWAS findings. These will inform us on genetic markers of EF - a key component of cognitive fitness.

Method: We analysed a subset of GWASs that used measures of *g* and EF as outcomes in healthy participants free from psychiatric, medical, or neurological conditions. A comprehensive SNP-based functional annotation was conducted, followed by in-silico gene expression and enrichment pathways analyses of SNP lists across the *g* and EF studies using bioinformatics annotation tools.

Results: The analysis identified two sets of SNPs associated with *g* (945 SNPs at $p<5x10^{-8}$ across 12 studies), and EF (53 SNPs at $p<5x10^{-6}$ across 4 studies) respectively. We found that while the *g* and EF SNP lists did not overlap, i.e. associated with different genetic variants, there is an overlap at the gene level, suggesting that different structural variants (SNPs) influence gene expression of the same genes in *g* and EF. Furthermore, pathways enrichment analyses indicated no overlap between 67 enriched pathways for g SNPs and 28 for EF SNPs ($p<0.05$). Taken together, our findings suggest overlapping (at gene level) but separable (at SNP and pathway levels) biology underlying *g* and EF.

Conclusions: Our preliminary findings suggest that more evidence is required to characterise the genetic overlap between *g* and EF. At the functional level these constructs appear to share some molecular mechanisms via common genes while exhibiting distinct patterns of biological pathways associated with *g* and EF genetic variants. These findings have important implications for navigating further research towards translatable genetic findings for cognitive enhancement and augmentation. One of the major limitations in our study is lack of consensus leading to huge heterogeneity in defining and measuring *g* and EF, which is reflective of this major problem in the field. An important step to overcome this limitation would be an EF-specific GWAS with sufficient power and adequately defined phenotype, leading to more grounded estimations of modifiability for key elements of cognitive fitness.

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Understanding demands, resources, and resilience during deployment at sea: Preliminary outcomes from interview data

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Background: Performance and retention are critical issues in the current operational environment for the ADF. The current maritime surface environment missions and operational tempo present a range of demands to crews that could not only impact on their cognitive functioning and job performance during deployments, but may also affect their emotional resilience. To date, there has been limited exploration of job demands and resources in the Navy context, particularly in relation to personnel resilience and performance during at-sea deployment.

Aim: The research is part of a larger program of research seeking to identify the effects of at sea- deployment with a focus on identifying the critical job demands, job resources, as well as personal demands and resources, that affect personnel outcomes. The outcomes of interest in this program of research are cognitive functioning, work performance, and emotional resilience.

Method: Semi-structured interviews of 25 Navy personnel (ranging across job role, responsibilities, and platforms) were conducted to determine: (1) key demands at sea that potentially affect wellbeing and performance, and (2) key resources at sea that support wellbeing and performance. Qualitative analysis has been undertaken to identify the key themes and critical factors affecting resilience and performance of Navy personnel in the at-sea deployment setting.

Results: This paper reports the initial findings of this qualitative analysis, focusing on implications for maximising resilience and job performance

Conclusions: Consideration will be given to how this preliminary data, and the associated data collection approach, assist us in identifying mechanism for better supporting personnel performance and resilience.

This research has been funded by DST Group Human Performance Research Network (HPRnet) to apply a multi-systems approach to investigate demand and resilience resource profiles within the at- sea deployment setting. The research is being undertaken by Macquarie University, Curtin University and the Leibniz Institute for Resilience Research.

Effects of the Human Gut Microbiota on Mental Wellbeing: A Scoping Study

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Background: The influence of the human-gut-microbiota on cognition has recently been reported on. However, the effects of how the microbiota influence aspects of mental wellbeing, a known disruptor of optimal warfighter performance, has not been discussed. Early data suggests that non-preferential bacterial communities are linked to mental wellbeing conditions and that modulation of the gut microbiota interventions may improve mental wellbeing.

Aim: The aim of this study was to review published research to identify what is currently known about the human gut microbiota and its relationship with mental wellbeing.

Methods: Research that was published from Jan 2010 to 01 Nov 2018 was reviewed to provide a deep insight and understanding on the human gut microbiota and its influence/link to mental wellbeing. After removal of duplicates, n=592/1765 items remained. Items were screened and synthesised by first using the title appropriateness (1), abstract (2) and finally full-text review (3). Included items were further categorised as human research and associated systematic literature reviews and reviewed accordingly. Two streams were applied for synthesis: 1) Exploratory gut-microbiota-brain links or 2) or an interventional design.

Results: A total of 28/592 reports were included for synthesis linking the gut microbiota and aspects of mental wellbeing. Five comparative research studies examined the link between the gut microbiota and measures of personality, stress or anxiety measures. Significant correlations between microbiota diversity and measures of stress and anxiety were identified when a known diagnosis was evident compared to healthy controls. Twenty-three studies were identified where an intervention(s) was implemented to modulate the gut microbiota to improve aspects of stress, anxiety or mood. Nineteen of the 23 studies demonstrated that modulation of the gut microbiota led to improved mental wellbeing metrics. Stress measures were the most profoundly affected, where probiotic interventions elicited improved effects subjectively, physiologically (e.g. cortisol and immune markers) and sleep quality improvement. In cohorts where "stressed" individuals were recruited (indicative of defence populations) microbiota interventions more often resulted in reduced physiological stress responses. The review also identified research gaps including: lack of studies with military samples, lack of longitudinal studies examining dosage effects, individual differences, and efficacy of combined interventions.

Conclusion: Limited studies were available to draw a detailed conclusion. However, available evidence suggests that gut microbiota is linked to stress and anxiety and that manipulation of gut microbiota could be a promising avenue for improving aspects of mental wellbeing, more specifically "stress". These findings warrant further research to address identified gaps. Impact to the ADF would include (but not limited to): 1) understanding which microbiota signatures influence mental wellbeing and job resilience and the link to cognitive/overall performance; and 2) identifying appropriate gut microbiota interventions that support/improve mental wellbeing of the warfighter to enhance overall performance.

Translating Cognitive Fitness Framework for Dual-use Application: A Performance-Focused Intervention for Athletes Affected by COVID-19 Disruption

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Background. As a new paradigm in the management of the Mental Health - Performer Wellbeing - Performance Support operating environment, CF2 (Aidman 2017, 2020) requires tools for its implementation. Its key building blocks are training protocols (modules) connected by a periodised training plan under the Cognitive Gym construct (Temby et al., 2015). Several stakeholder groups have adopted CF2 including corporate trainers, mainstream psychological practice operators, as well as members of specialist groups such as the College of Sport & Exercise Psychologists (CoSEP) of the Australian Psychological Society (APS). CoSEP identified a pressing requirement to assist athletes and their support teams severely impacted by the COVID19 disruption to the sports industry. Multiple delays compounded by quarantine and self-isolation restrictions have been observed to cause severe disruption to the heavily regimented training cycles and mental well-being of all involved.
Mental Health support through the Australian Institute of Sport (AIS) and other service avenues including Telehealth, is essential. However it does not address key aspects of the performance focus that is critical for this audience.

Aim. Re-setting and adjusting training rhythms and focus on maintaining and improving mental fitness is one of CoSEP's recognised areas of expertise. The COVID-19 disruption to the entire sports industry is driving CoSEP's interest in fast-tracking the development of CF2 training modules – especially those that are relevant to the current pressures facing the industry.

Method. CoSEP experts have commenced a practitioner-led modular program development for an app-enhanced implementation. The modules cover Composure, Mindset and Self-belief, Recovery and Resilience, and Mission-Ready. Module development is ongoing. Evaluation of training efficacy and user experience is to follow.

Conclusion. This project can deliver immediate value to a high-profile user group severely challenged in the current, highly unusual operating environment. It is also generating prototype Cognitive Gym modules for multiple applications and industries, and even for broader consumer application (e.g., school students challenged by remote learning). It represents a practitioner-led collaborative response to a high-profile crisis-affected industry that will potentially benefit and ease the burden on many other groups now and into the future.

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Exploring the intra-individual reliability of tDCS; A Registered Report

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Background: Non-invasive brain stimulation is a powerful neuromodulatory technique that is extensively used in research and clinical settings to investigate/modulate the causal mechanisms of in-vivo brain function (Nitsche et al, 2006; Marshall & Binder, 2013) and to improve performance on various motor, cognitive and perceptual operations (Nitsche et al., 2003; Filmer et al., 2017; Martin et al., 2014), In particular, the use of transcranial direct current stimulation (tDCS) – a non-invasive brain stimulation technique in which a weak electrical current (0.5 – 3mA) is applied to the scalp – has surged in recent years (Filmer, Mattingley & Dux, 2020), and has recently been noted for its potential application for enhancing performance in military personnel (Brunye et al., 2019; Davis & Smith, 2019; Feltman et al., 2020; Brunye et al., 2020). However, the marked increase in tDCS studies has been accompanied by variable results, bringing the reliability of this method into question. Although a number of meta-analyses have concluded that inter-individual and intra-individual differences strongly contribute to variable tDCS results (Bastani & Jaberzadeh, 2012; Hoy et al., 2013; Hill, Fitzgerald & Hoy, 2016; Medina & Cason, 2017), very few experimental papers have sought to directly explore the reliability of tDCS. Given the increased demands and practical limitations of military training environments, an understanding of tDCS reliability is vital if the utilization of this technology for defence personnel is to become a reality.

Aim: Thus, in order to address this shortfall in existing literature we propose an adequately powered, pre-registered, double-blind and sham-controlled crossover study, which aims to assess the intra-individual reliability of two separate single-session tDCS montages at producing previously replicated behavioural effects.

Method: A single cohort of individuals (*N* = 100) will undertake a total of eight behavioural training sessions, four with a cognitive task (Response Selection Task; Filmer et al., 2013) and four with a motor task (Serial Reaction Time Task; Nissen & Bullemer, 1987). Active tDCS will be delivered to participants during half of the sessions, two of each task modality, with sham stimulation delivered for the remainder. The schedule of tDCS and sham sessions will be staggered and counterbalanced across participants and spread over two time periods such that participants complete a tDCS and sham session with task A in week 1 and repeat those sessions in week 2. Bayesian t-tests will be used to compare task performance, reaction times (RTs), between conditions in each time period. These differences in RTs will then be standardized and subjected to intra-class correlation analysis in an attempt to estimate the intra-individual reliability of these montages across time periods.

Results: This study is currently undergoing submission as a Registered Report, and as such data collection has not commenced.

Conclusions: This proposed registered report represents the first of its kind, as no other pre-registered study has yet to specifically examine the reliability of tDCS at eliciting behavioural effects in such a large cohort and across two task modalities. Thus, our results will not only provide valuable information to the ongoing tDCS research within the military domain, but will also make a sizeable contribution to the field of non-invasive brain stimulation.

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Neural Substrates of Cognitive Enhancement a Combined Brain Training and Non-Invasive Brain Stimulation

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Background: Automation and technology are reducing the physical workloads in our lives at the expense of increasing our cognitive workloads by requiring monitoring and subsequent action on multiple simultaneous tasks (Strobach, 2019). To maintain optimal performance on multiple tasks, practice is required. Combining brain stimulation with multi-tasking training has shown multi-tasking performance improvements beyond what training alone can achieve (Filmer *et al*, 2017a) and transfer of performance to untrained tasks (Filmer *et al*, 2017b). Currently it is unknown how brain function changes as a result of paired training and stimulation protocols, or how such changes are related to brain structure or neurochemical concentrations. By using an established cognitive training and electrical brain stimulation protocol combined with state-of-the-art neuroimaging techniques, we aim to provide comprehensive evidence for the efficacy of combined cognitive training and brain stimulation for enhancing performance as well as elucidating the underlying neural substrates of any training+stimulation induced changes. Crucially, this work will also provide definitive evidence on individual differences that predict the response to these training and stimulation interventions.

Aims

1. How tDCS+training leads to performance changes on trained and untrained cognitive tasks.
2. How baseline measurements of genetics, neurochemical concentrations, cortical morphology, and functional activity correlate with individuals' outcomes to tDCS+training.
3. How neurophysiology (neural activity, functional networks, and white matter) changes as a result of combining tDCS+training.

Method: In the largest study of its type to date, we combine 4 days of multi-tasking training and tDCS with multiple neuroimaging techniques such as functional magnetic resonance imaging and diffusion tensor imaging to disentangle the neurophysiological mechanisms that underlie how the brain changes with training, and how modulating its performance with tDCS may affect these mechanisms. We obtain other physiological data such as participants' genotypes and neurochemical concentrations to use alongside the aforementioned techniques to correlate with participants' response to training+tDCS. To ensure the robustness of the findings, we use a large sample size of 275 healthy, young adult participants, divided into 5 groups; 4 control groups and the tDCS+multi-tasking training group. To characterise transfer effects, w 9 different tasks, assessing both near and far transfer.

Significance: This study, with its large sample size, established training protocol, optimised stimulation parameters, and rigorous controls, will give definitive evidence on the efficacy of tDCS in enhancing the gains from multi-tasking training. It will give significant weight to the benefits ascribed to tDCS by several recent studies looking at the implementation of tDCS in military settings (Davis & Smith, 2019; Brunyé *et al,* 2020), as well as to the broader non-invasive brain stimulation research community. In addition, the individual differences analyses looking to elucidate potential genetic, neurophysiological, and neuropsychological predictors of response to tDCS and multi-tasking training, will be invaluable to optimising the future use of tDCS in therapeutic, military, and research domains.

Acknowledgements: The Commonwealth of Australia is supporting this research through a Defence Science Partnerships agreement of the Defence Science and Technology Group, as part of the Human Performance Research Network.
This research was also supported by an Australian Research Council (ARC) Discovery grant (DP140100266, PED & JBM), the ARC-SRI Science of Learning Research Centre (SR120300015, PED & JBM), and the ARC Centre of Excellence for Integrative Brain Function (ARC Centre Grant CE140100007, JBM). JBM was supported by an ARC Australian Laureate Fellowship (FL110100103), HLF by a UQ Fellowship (UQFEL1607881) and an ARC Discovery Early Career Researcher Award (DE190100299). SE & YW acknowledge support through the Australian Government Research Training Program Scholarship

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The power of panorama? Exploring visual search tasks in a simulated submarine control room

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Background: Advances in opto-electronics has enabled replacement of optical path submarine periscopes by digital non-hull penetrating periscopes. To explore key HMI (Human Machine Interface) design drivers for such systems two experimental HMIs focusing on specific elements were developed using a Cognitive Work Analysis-based process (Schmitt et al. 2013). The first represented digitisation of optical path periscope use conventions presenting a narrow rotating visual image of a horizon (labeled *Optix*). The second presented an additional segmented 360 degree panorama (an OPTical IMagery Usability System [*OPTIMUS*]). Cognitive theories of visual attention and search suggest that humans are efficient at detecting objects with unique features in parallel (Wolfe, 1998). Hence, OPTIMUS seemed to offer advantages for contact detection and understanding situation layout. By contrast, Optix potentially reduced the chance of operator visual overload due to a smaller visual arc – with the potential cost of slowing visual search of a 360 degree horizon. The two HMIs were experimentally compared in the Control Room Use Simulation Environment (CRUSE).

Aim: The aim of this study was to compare the accuracy and speed with which participants could detect contacts using the OPTIMUS and Optix HMIs at different magnification settings, and as a function of contact distance from Ownship. We expected that OPTIMUS would support more accurate and faster contact detection according to visual search theory.

Method: Twelve trained novice participants completed three 6-min scenarios using the Optix system and three 6-min scenario using the OPTIMUS system (order counterbalanced). Participants were instructed to click on the image of each contact as soon as they saw it. Participants were tasked to use a different search strategy (high magnification, low magnification, and a hybrid of high and low magnification) for each scenario. There were 10 close contacts and 10 distant contacts to be detected in each scenario.

Results: Preliminary findings suggest that the proportion of contacts detected (hit rate) may be higher using OPTIMUS compared to Optix but perhaps only in certain search strategies. Detection speed does appear to be faster in OPTIMUS suggesting that human parrallel visual search capacities could be harnessed in some contact search strategies. OPTIMUS was rated as more usable than Optix.

Conclusions: Future HMI design, logically, should benefit from supporting psychological insights such as human parallel visual search. However careful empirical studies are suggestive of subtle implications for task performance and may depend on *use strategy.* These issues will need to be accounted for to achieve an optimal HMI design. Follow-up studies will examine other relevant tasks such as classification and localisation; participant workload and situation awareness; and the potential benefits of sharing imagery amongst a team.

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Investigating the role of individual alpha frequency on information processing in a virtual reality navigational setting

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Background: Exploring inter-individual differences in cognition provides valuable insight into information processing in everyday life; one marker of these differences is the individual alpha frequency (IAF; Corcoran et al., 2018). IAF is a unique electrophysiological biomarker quantified as the frequency in which the peak power of the alpha band in the brain arises. It typically ranges from 8- 13Hz and has been strongly linked to information processing and model updating speed (Bornkessel et al., 2004; Klimesch, 1999; Klimesch et al., 2007; Samaha & Postle, 2015). However, this research is based around highly controlled experimental designs, which may differ from the application of a real- world task and environment. In order to generalise this literature to a real-world context, IAF research should implement the use of evolving technology, such as virtual reality (VR).

Aim: The aim of the present study was to advance the current understanding of IAF's role on information processing in a digital facsimile of a real-world environment. We implemented a maze task in VR to explore IAF in a navigation environment, to determine how individuals use working memory, perceptual and attentional resources in everyday life. It was hypothesised that individuals with a higher IAF would perform better on the maze task when aided by a map, and those with a lower IAF would consult a map more frequently.

Method: Nine healthy participants (female = 1, mean age = 27 years, range = 21-35 years) were recruited from the general public. A 3D maze-like environment was created in the Unity game engine and presented with a VIVE Pro VR system. Participants were instructed to navigate these environments in order to locate and identify 10 targets whilst equipped with one of four unique navigational aids; two represented maps, the third represented X-ray vision of aforementioned targets, and the last represented beams of light protruding above the targets. EEG data were recorded in order to obtain IAF using a LiveAmp with 32 electrodes mounted in an elastic cap. All statistical analyses were conducted in R in order to investigate the effects of IAF on maze performance on the navigational task.

Results: The results showed that IAF did not have a statistically significant impact on performance in the maze task, however the trend observed in the present study suggests that individuals with a lower IAF performed better on the task when compared to higher IAF individuals. Further, those with a lower IAF consulted the handheld map more frequently, however the correlation was weak and nonsignificant.

Conclusions: These findings suggest that IAF alone is unable to account for differences in performance on tasks of processing speed and executive function. Further, this may indicate that the effects of a higher IAF may arise only when presented with a highly complex task, as behavioural data showed a high level of accuracy for target identification. Alternatively, IAF may better represent the use of different perceptual strategies that may or may not optimal for the present task. This research provides a first step for the use of quasi-realistic settings in the investigation of IAF.

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Session 4 – Training & Simulation

The effect of mobile app-based multitasking training on situation awareness and performance in Army personnel

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Background: The Australian Army seeks to enhance the cognitive performance of personnel, including through the use of novel training technologies. A key to successful performance in complex environments is Situation Awareness (SA), the awareness of what is occurring in an individual's environment.
Previous research (e.g., Bender et al, 2018) demonstrated that SA is underpinned by multitasking, the ability to attend and respond to multiple information sources concurrently or in quick succession of each other. A previous study (Black et al., 2019) with university students suggested that mobile app- based multitasking training decreased workload and benefitted complex task performance. However, to date there has been no attempt to explore the benefits of multitasking training in a military cohort.

Aim: The aims of the current study were to explore the impact of multitasking training on SA, complex task performance, and workload in a military sample. This study was part of a larger collaboration between academia, Defence Science and Technology, and Army.

Method: Participants were 154 enlisted Australian Army personnel from a range of Corps and ranks. Participants were randomly allocated to an experimental group receiving app-based multitasking training, an active control group receiving app-based visual search training, or a passive control group. SA, workload and performance were compared before and after training on an Air Traffic Control (ATC) simulation, in which participants were required to manage a busy sector of airspace. SA was measured with the Situation Present Assessment Method (SPAM) technique, and subjective workload was assessed using the NASA TLX scale.

Results: ATC aircraft acceptance and handoff improved more for the app-based multitasking training group than for either control group, but the effect did not reach significance. There was no significant benefit for conflict resolution or SA. Subjective workload improved post-training for all groups.
Importantly, we also found considerably lower compliance rates with training amongst Army participants (57%) than amongst the undergraduate university students in our previous study (92%).

Conclusions: App-based multitasking training did not significantly transfer to complex task performance, highlighting the difficulties of translating research from laboratory to military settings. Benefits seen for workload across all groups were likely due to practice effects on the complex task, rather than cognitive or perceptual training. Moreover, of key importance to Army's training transformation, the lower levels of uptake of the app training signals the need to ensure "buy-in" from users to foster the success of future on-demand digital services such as training apps and other instructional tools.

This study adds to the understanding of SA and cognitive training. The acquired knowledge will assist with design and successful deployment of future digital training and educational aids. The study also demonstrates what can be achieved through collaboration between academia, DST, and Army.

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Acknowledgements
The Commonwealth of Australia supported this research through an Australian Government Research Training Program Scholarship, the Australian Army and a Defence Science Partnerships agreement of the Defence Science and Technology Group, as part of the Human Performance Research Network.

Exploring the utility of mobile apps for training and learning in the Australian Army

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Background: With new technologies emerging rapidly, organisations are changing the way they view and implement training. Defence force training is complex and unique, and the Australian Army is interested in optimising training outcomes through new technologies as part of a broader training transformation strategy (Australian Army, 2020). Of particular interest are mobile applications commonly referred to as 'apps'; software programs designed for smartphones and tablets. These have become widely utilised for training purposes in civilian sectors, and there is evidence for their training effectiveness. However, compared to civilian sectors, there have been few studies examining the uptake of mobile apps in the military context.

Previous studies with military populations in Australia and overseas have found mixed results, with personnel reporting positive attitudes to using mobile apps but variable usage rates (e.g., Black, 2019; Grant & Pavlovic, 2015). These findings suggest a need to better understand enablers and barriers to mobile app uptake among military personnel. The current study was motivated by these findings and sought to elicit the perceptions of military personnel towards using mobile apps for training and learning, and the optimal circumstances for such technology in the military. Given current military interest levels in new training technologies, it is important that these issues are addressed to inform future research efforts and investment decisions.

Aim: The aim of the current study was to explore the attitudes and experiences of Australian Army personnel regarding the use of mobile apps for military training and learning, including perceived benefits, opportunities, and barriers to uptake.

Method: The study received approval from a Human Research Ethics Committee prior to data collection. Given the exploratory nature of the study, a qualitative research design was employed. Individual semi-structured interviews were conducted by e-mail, phone or video-conference with a cross-section of Australian Army personnel from different ranks and corps. Participants were recruited using a combination of purposive and snowball sampling, with recent experience using mobile apps being a requirement. Interview questions were informed by previous research (e.g., technology acceptance model; Venkatesh & Davis, 2000) and explored device ownership and use, mobile app experiences and preferences, perceived benefits, opportunities, and challenges. Braun and Clarke's (2012) six step thematic analysis approach was used to examine the data for key themes using both deductive and inductive methods.

Results: Data collection is still in progress and the study findings will be reported at the symposium.

Conclusions: The study outcomes will be important for (a) understanding current enablers and barriers to the uptake of mobile training apps in the Australian Army, (b) identifying where mobile apps could have greatest benefit for Army personnel, and (c) shaping future research in support of Army's training transformation strategy. The study also highlights how "more together" can be achieved through integrated and collaborative human sciences research involving academia, DST, and
the ADF.

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AARs – Facilitating Team Learning for Improving Performance In Combat Forces

PUBLIC RELEASE

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Background: One focus of the continuing 'CTC 2025' modernisation program is on After Action Reviews (AAR) undertaken during challenging combat preparation exercises (Hill & Reilly, 2017). Partnered with the training combat forces, Observer Trainers (OT) facilitate AARs and employ reflection techniques to create a basis for future action. Army doctrine highlights AARs as supporting the 'continuous pursuit of improvement', that in turn supports the development of 'professional mastery' (Army, 2015, 2018). Although the doctrinal AAR process appears intuitively sound, initial research insights, from both the high-readiness forces undertaking training and CTC OTs, has confirmed dissatisfaction with the AAR (Reilly, 2020).

With no agreed theoretical basis for the effectiveness of AARs CTC is conducting empirical research into the efficacy of the Australian Army AAR (Kaliner, 2013; Reilly, 2020; Villado, 2009). Initial insights, from the on-going empirical research, confirm the importance of highly trained facilitators to support teams in deep learning and performance improvement (Reilly, 2020). Spring-boarding from the research, CTC-Live have significantly revamped the OT as a facilitator approach, in supporting AARs, to better scaffold learning during complex and challenging exercises (Khachadoorian & Mackenzie, 2020; Villado, 2009). Ensuring that OT are best prepared to facilitate learning will improve AAR effectiveness (Keiser & Arthur, 2020).

Aim: This research is evaluating the efficacy of the AAR in Army advanced collective combat training in order to improve support to high readiness combat units.

Method: Employing a constructivist approach, AAR artefacts, from the broader Army and CTC, are being thematically analysed together with the results of in-depth interviews, conducted with a range of very experienced stakeholders (19 General and Senior Officers, 6 Senior Warrant Officers, 4 x other).

Results: Several factors issues impacting upon the efficacy of the AAR so far have been identified and while the analysis remains on-going, to date, they include: the exercise goals; the AAR aim and timing; the facilitator skills; the Training Unit team's approach, meta-cognitive abilities and learning agility; the AAR process flow; the Australian military culture; and, the AAR expected outputs.

Building on the research insights, CTC-Live OTs are innovating by reflecting on their 'facilitating' experiences. Partnered and embedded with Training Units throughout exercises, OTs provide support to learning through bespoke feedback. During AARs, OTs utilise the shared experiences of these high-readiness teams, to facilitate learning and develop action plans for future improvement. CTC OTs are piloting a range of advanced facilitation techniques to more effectively: engage teams; support shared mental model development; activate targeted group reflection and analysis; support team self-assessment; and, the construction of future-focussed action plans. Skilled OT facilitators are crucial in guiding Commanders and teams through this REVIEW and REFLECT to ANLYSIS and ACTION process. CTC-Live will continue to review and adapt their OT training programs in partnerships with high-readiness combat units.

Conclusion: This presentation will: provide an overview the on-going CTC sponsored research into the effectiveness of the AAR and Collective Training; highlight the CTC partnered approach; detail the advanced facilitation techniques already introduced; and, outline some of the initial responses to the changes made in facilitating CTC AARs.

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Performance Edge VR: An implementation trial to evaluate efficacy and usability of a modular biofeedback-enhanced stress management platform

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Background: The Australian Defence Force (ADF) currently utilises BattleSMART as the primary vehicle for the delivery of stress management training (Cohn, Hodson et al. 2010). BattleSMART involves the classroom based presentation of introductory stress management content by expert instructors. There was a recognised need to complement this introductory training through the addition of an interactive platform for skill acquisition training. The requirements for this platform included a focus on ab initio/initial entry trainees and reduced implementation burden, which in turn required the capacity to be scalable, evidence based, objectively assessable and remotely deployable. In response to these requirements the Centre for Advanced Training Systems at the University of Newcastle partnered with ADF psychologists to create Performance Edge VR platform. The platform is a virtual reality based, biofeedback-enabled, modularised system designed to enable the acquisition of proven stress management techniques (Powers, Zum Vorde Sive Vording et al. 2009).

Aim: The operating environment, user interface and the first module on controlled breathing has been evaluated in 3 distinct research settings and trials addressing efficacy, usability, acceptability, and robustness.

Method: The operating environment, user interface and the first module on controlled breathing has been evaluated in multiple contexts for efficacy, usability, acceptability and robustness.

Results: Initial efficacy of the controlled breathing module was examined in three repeat sessions (separated by a week-long interval) in a university campus-based convenience sample (n=30). Results showed that the three weekly sessions of biofeedback-assisted training of controlled breathing produced both behaviour change and objective improvement in breathing metrics. Acceptability and usability of the module was next evaluated in military trainees (n = 70) from Army, Air Force and Navy, who provided feedback on Performance Edge VR, including its usability, design, user experience, self-reported knowledge transfer and in-training efficacy. Overall feedback was consistently positive. The biofeedback functionality and immersive nature of the application were rated as particularly valuable. Finally, we have examined the ability of controlled breathing training delivered via Performance Edge to facilitate de-escalation of combat arousal following engagement in a simulated intense, close quarter urban combat training scenario (n = 40). Data from this evaluation has indicated that a single session of Performance Edge is sufficient to significantly assist trainees to de-escalate arousal status after exposure to a simulated direct fire engagement.

Conclusion: These results confirm the utility of Performance Edge VR platform, and its Controlled Breathing module, in delivering stress management training in realistic workplace settings within the ADF.

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Using Epistemic is to Model Individual and Team Performance

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Background: Modelling the processes of individuals and teams is essential to improving performance in collaborative settings. For such models to be effective, they need to provide actionable and understandable insights for educators, trainers, and the teams themselves.

Aim: Here, we synthesize prior work that (1) used Epistemic Network Analysis (ENA) (Shaffer et al., 2016) to model individual and team processes in the context of air defense warfare, and (2) proposed a real-time system for monitoring individual and team performance. Our goal here is to introduce this work in a new context and describe how its generalization can enhance defense capabilities.

Prior Work: Our prior studies have shown that ENA has interpretive and statistical advantages for modelling team contexts compared to other techniques (Swiecki et al., 2020; Swiecki, Lian, et al., 2019). Importantly, ENA allows us to model processes at the team level, but also at the individual level in a way that accounts for the interdependencies that exist between teammates. This flexibility means that ENA can be used to describe team effects, individual effects within the team context, and differences between individuals due to roles. Our prior work (Herder et al., 2018; Swiecki, Ruis, et al., 2019) has also shown that ENA models can be simplified and integrated into systems for monitoring collaborative performance in real-time, guiding interventions, and scaffolding after-action review.

Conclusions: The general process implied by our prior work suggests that similar models and systems can be built for new contexts by (1) identifying salient domain behaviours (2) developing classifiers for those behaviours (3) modelling relationships between behaviours at the team and individual levels using ENA, and (4) simplifying and integrating the models into real-time interfaces. We propose that this process could be implemented in a variety of defense contexts to support team training and, eventually, real-time monitoring of performance in actual defense situations.

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Mixed Reality in Distributed Teams

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Background: Teamwork is predicated on shared understanding of a task and the ability to coordinate information and actions. Teams that are physically distributed expand organisational flexibility, but individual and team performance can be negatively impacted (Fiore et al., 2003). The distribution of teams may reduce situational awareness and knowledge of command intent. Furthermore, in the tactical environment, military teams operate under significant time pressure where they make complex, high-stakes decisions based on incomplete information. Mixed Reality provides new opportunities for team collaboration through richer shared experiences (Ens et al., 2019), and has potential to improve information sharing and command and control between distributed teammates. Human-centric research is necessary to evaluate Mixed Reality at the tactical level, and explore the potential performance and decision-making benefits that may be enabled by its application.

Aim: To investigate whether Mixed Reality technology facilitates improved performance in a distributed team scenario relative to existing communications technologies.

Method: Participants will be randomly assigned to one of two participant conditions: Leader or Agent. Participants will then be randomly assigned to teams consisting of one Leader and one Agent. Teams will be physically separated and will be required to complete a number of collaborative, time- pressured problem-solving tasks. How teams coordinate their actions and share information will be manipulated across three testing conditions: verbal communication only, verbal communication and shared visual display (through a live visual feed), and verbal and mixed reality communication (through Mixed Reality headsets). Participants will complete four different problem-solving tasks that require coordination between the Leader and Agent, with each task evaluating team coordination under unique conditions of cognitive and physical demand. To counterbalance individual differences, control learning effects and reduce simulation sickness, teams of participants will complete tasks under different communication conditions.

Four tactical-analogue, problem solving tasks were developed by the authors specifically for this study. The first is a labyrinth task where the Agent is in a virtual labyrinth and the Leader has an overview map of the labyrinth and must identify the Agent's location. The second is a spatial block assembly task where the Agent is given physical blocks that they must assemble into a specific pattern only known by the Leader. The third is a virtual barrier task where the Agent must move resources into a safe base while avoiding barriers that only the Leader can see. The fourth task is an escape room puzzle where the Leader and Agent must work together to decipher clues to locate items in the Agent's room. All tasks were created to gauge team performance and decision-making under different cognitive demands and unique operational use-cases.

Intended Outcomes: Data collection is expected to commence in early 2021. The study will provide valuable insight into the potential utility of Mixed Reality for enhancing performance and decision making in distributed teams. In the current presentation, our intention is to share our experimental development process regarding the design of time-critical Mixed Reality tasks, and experimental methods and design, and gain DHSS Community feedback on our approach.

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The role of automated human-performance measurement for enhancing training effectiveness and warfighter readiness

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The measurement of human performance underlies the capacity of training simulations to effectively prepare warfighters for complex, high-intensity environments, and manage, improve, and sustain their readiness. Individual and team performance in training events have traditionally been assessed subjectively by highly experienced personnel with subject matter expertise. However, given the increasing complexity of these training events, often involving a large training audience distributed across multiple locations, it is possible that some critical learning points are missed by assessors due to limits on cognitive-attentional resources and visual-perceptual processing. It is under these circumstances that automated, multidimensional, human-performance metrics could augment the role of assessors by providing automatic and near-real-time monitoring and visualisation of performance. In this presentation, I will review recent scientific advances that suggest that both spatial and temporal metrics of performance, and physiological and behavioural measures of cognitive state, have the potential to greatly enhance the training effectiveness of both individuals and teams.

Spatio-temporal metrics of performance are those measures relating to the linear and/or non-linear relationships between any entities of interest in the mission simulation environment. Research has shown that these measures can be used to assess proficiency levels on core competencies, track changes in proficiencies over time, and provide real-time visualisations of performance. More recently, research on team performance from the sports sciences has demonstrated interesting non- linear metrics that that could be used in warfighter training. However, while spatio-temporal measures have the potential to provide reliable and robust diagnostics for assessment and feedback, a complete diagnosis of performance can only be achieved when the assessor has information about the cognitive factors that may have led to decrements or improvements in training performance.

Recent research on the relationship between physio-behavioural measures and cognitive state has the potential to provide insight into the cognitive factors leading to changes in performance. For example, some of this research has shown that measurement of the overt attention of individuals can be achieved via gaze tracking, shared situation awareness can be measured via dynamic systems modelling of team communication dynamics, and operator workload can be accessed via heart rate dynamics and machine learning models of voice frequency characteristics. Furthermore, these measures can be combined using multivariate approaches to provide accurate information about how teams coordinate their behaviour, how individuals contribute to overall team performance, and how team behaviour changes in response to perturbations to the technological and environmental systems in which they are operating.

While the research described above has great potential for performance measurement, it is not without challenges. For example, individual differences in response to workload and stress, the large amounts of data required to improve the accuracy of models, and the generalisability of results across different contexts and domains, are just some of the concerns that need to be addressed. Notwithstanding these challenges, the role of automated human-performance measurement is a necessary next step in simulation training, assessment, and feedback that will greatly enhance training effectiveness and warfighter readiness.

DHSS 2020 – Abstracts | Day 3

Session 5 – Autonomy & teaming

EEG-based Evaluation of Virtual Unmanned Vehicle Control Systems

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Background: The modern soldier may soon be equipped with futuristic and powerful technologies to support soldiers controlling unmanned vehicles. An advent such as this will undoubtedly impact a soldier's field performance, but little research to date has examined the cognitive impact. Although some studies have examined the effect of cognitive performance of operating unmanned vehicles (Sterling & Perala, 2007; Velagapudi et al, 2009), and differing degrees of automation in unmanned vehicles (Dixon, Wickens & Chang, 2005; Taylor et al, 2013; McKendrick et al, 2014; Hooey et al, 2017), these did not explore the effects of augmented reality (AR). Similarly, studies (Baumeister et al, 2017; Volmer et al, 2018) have explored the cognitive impact of AR, but not unmanned systems.

Aim: While the introduction of technologies such as unmanned vehicles and AR may be exciting, designing optimal control interfaces for them is a difficult, expensive and time-consuming task. Our first aim was to address these problems by building a simulated environment in which soldiers could test new technologies without requiring expensive physical hardware. A virtual reality (VR) environment enabled us to rapidly employ new design ideas and test them in simulated combat situations. Our second aim was to measure cortical responses with electroencephalography (EEG) to changes in the virtual environment and evaluate the drone control systems provided to them. An experiment was designed to answer two research questions: Can EEG inform the design of AR task assistance? Can EEG inform the design of unmanned vehicle control interfaces?

Method: Ten adults were recruited from members of the general public. A 3D virtual environment was created using the Unity game engine and presented to the participant using a VIVE Pro VR system. The environment represented a maze, with the intention for this to abstractly resemble an urban environment where corners and visual occlusions can inhibit line of sight. Players were tasked with navigating the maze, aided by five different visual conditions with the aim of finding and responding to hidden targets. EEG data were recorded using a LiveAmp with 32 active Ag/AgCl electrodes mounted in an elastic cap. The EEG data were analyzed using the Python MNE package and the average alpha power measured in each condition was statistically analysed using R.

Results: The results showed that alpha power fluctuations are sensitive to manipulation of the virtual drone control system, making it a powerful and potentially real-time measure of a control system’s difficulty of use and cognitive impact on the user.

Conclusions: The results showed that our drone tools and visualizations have had both positive and negative impacts upon response time, and that this is explained in more depth by the alpha power response. Importantly, our experiment has shown that enriching the design process with EEG can reveal underlying cognitive explanations for observed performance. In addition, our ability to filter the EEG signal, despite wearing an HMD and having free movement opens the door to a raft of other potential experiments, perhaps even to testing with actual soldiers in the field.

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Are Two Heads Always Better Than One?

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Background: Technological advances have increased the ability of geographically distributed individuals to work collectively in dynamic environments. Teams use communication to share and process information and effective communication may reduce errors. We were interested in how naïve (newly formed and untrained) teams evaluate performance as it may shed light on why teams succeed or fail. Furthermore, we examined the relationship between communication patterns and performance on a dynamic simulation.

Aims: 1) Examine the cues used by naïve team members to evaluate their own (self) and their teammate's (other) subjective performance during a dynamic simulation; and 2) Examine the relationships between patterns of communication and three simulation-derived metrics of team performance.

Method. 108 Australian undergraduate students completed the study in 54 two-person teams (70 females; mean age = 19.85, SD = 5.19). Participants completed a simulated emergency driving course in an urban environment and performed one of two roles: driver or Uninhabited Aerial Vehicle (UAV) operator. The team's goals were to drive as quickly and safely (i.e., maximise speed and minimise collisions) while staying on a directed route. The driver controlled an emergency vehicle and the UAV operator tracked the driver's changing operational conditions and provided information/instruction to aid the team's goals. Team members were seated in different rooms but could freely communicate via headsets. Team performance was captured by speed, collisions, and distance travelled metrics. Using video recordings, we computed the frequency and quality of team communication, such that all verbal utterances were coded into one of nine categories. We also measured NASA-TLX, psychological resilience, executive functions (task switching, inhibition, and working memory), fluid intelligence, and Big-5 personality. First, participants completed a demographic questionnaire then the driving simulation, followed by the psychometric measures.

Results: Both team members did not use a common set of cues to assess performance. Self- evaluations tended to be associated with emotional cues and perceptions of the other teammate's performance which had no relationship with objective performance. Evaluations of the other were related to objective performance but the relationship was positive for UAV operators and negative for drivers. Next, we performed an Exploratory Factor Analysis on the communication measures to extract three factors that characterise different patterns of communication. They were: Inconsistent UAV (mixed quality), Supportive Exchange (high quality), and Detrimental UAV (low quality). The Supportive Exchange factor negatively predicted speed and the Detrimental UAV factor positively predicted collisions and distance travelled, after accounting for control variables. A trend analysis of the communication factors and team performance revealed significant linear components only.

Conclusions: Naïve team members were (mostly) misguided in their subjective appraisals of performance which has implications for objective team performance. Low quality patterns of communication tended to have a pernicious effect on errors (i.e., collisions and distance travelled), and high-quality patterns of communication tended to have a detrimental effect on speed. It appears there is always some performance cost when naïve teams work together on a dynamic task. Thus, their use should be carefully considered as two heads may not always be better than one.

Error-related brain activity differs when observing a human and autonomous system perform the same target recognition task

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Background/Aim: There is current interest in adapting EEG correlates of human performance monitoring (e.g. error-related potentials) into human-autonomous system teaming scenarios to improve team outcomes by developing brain-based measures of system performance monitoring and human trust in automation (Drnec et al., 2016; Somon et al., 2017). Although error-related potentials have been elicited from human observers of system performance using simple laboratory tasks (de Visser, et al., 2018; Somon et al., 2019), little research has replicated this using complex tasks in ecologically valid settings. Additionally, translating knowledge of human performance monitoring to system performance monitoring may be difficult as brain responses reportedly differ when monitoring humans compared to systems (Somon et al., 2019). Our study aimed to address these issues.

Method: We created a novel image categorisation task based on the Asirra CAPTCHA (Elson, et al., 2007) and randomly assigned forty-eight participants (34 female; mean age: 25.5 years) as monitors of either a virtual human or an autonomous system partner. Participants needed to locate one target from four simultaneously presented images and then saw visual feedback in either the attended location, confirming a correct partner choice, or a remaining unattended image location indicating an error. Participants were advised partners would be accurate on approximately 80% of trials and regularly rated observed performance against this expectation while also predicting future performance. Error rates varied unpredictably and observed performance sometimes matched expectations and at other times was better, or worse. Observed performance did not differ between partners.

Results: Linear mixed-effects models were run to predict both partner monitoring accuracy and predicted partner performance by partner type and error rate. Results showed a significant effect of error rate on both variables, however no other effects were significant, suggesting participants monitored and predicted performance similarly for the different partner types. We calculated event- related potentials at partner feedback, sorted by partner type, error rate, and partner accuracy. Results revealed a feedback-related negativity (FRN) to errors for both partner types peaking 240ms after feedback over frontal-central electrodes and modulated by error rate. The FRN was followed by a frontal P300 (P3a) component unique to human errors, while a posterior P300 (P3b) was observed to errors for both groups, increased for system errors and again modulated by error rate. A linear mixed-effects analysis showed significant partner x accuracy x error rate x topography interactions for the FRN and P300 components.

Conclusions: As the FRN was elicited by feedback in unattended locations while participants visually attended correct targets, our results indicate the FRN may be utilisable as an indicator of system performance in complex task environments. Interestingly, despite identical observed performance and no behavioural differences we observed a frontal P3a uniquely to human errors. The P3a is reportedly sensitive to social contexts (de Bruijn, et al., 2009), fitting our result as the protocol differed only in the type of partner observed. Our results support the potential use of the FRN in system monitoring, while highlighting the need to consider how monitoring different agent types may influence obtained EEG components.

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Telexistence: Mitigating the Human Risk Associated with Operating in Hazardous Environments

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Background: Developments in remote, robotic and sensory technologies in recent decades have led to an increased ability to operate differently in challenging environments. For defence and security communities, this includes significant steps to remove the need for people to be present in potentially hazardous locations. To facilitate this advancement, the Defence Science and Technology Laboratory (Dstl) is currently investigating the utility of a telexistence capability for United Kingdom (UK) defence and security.

A telexistence capability can be defined as a system, or a system of systems, which allows a human user to operate in an environment without physically being there. This could be achieved by using a real-time, remotely operated avatar which relies on the integration of:

- Telepresence
  - a visual-audio solution which enables a human operator to experience the sensation of self-presence in a remote environment

- Haptic feedback
  - an immersive solution which transmits sensory information from the remote environment to the human operative

- Robotics
  - a manoeuvrable solution which enables a human operator to interact with the remote environment

Defence Benefit: A telexistence capability has been identified as a means by which skilled operatives can transfer their practice to a remote location, which can enhance the speed to which they are deployed. This technology can also be used to keep military personnel safe by reducing the risks associated with operating in hazardous environments, for example: explosive ordnance disposal (EOD), Chemical, Biological, Radiological, Nuclear (CBRN), space exploration, firefighting etc.

Current Research: Through collaboration with end users, industry and academia, this project aims to understand the technical possibilities and potential applications of telexistence technologies within the defence and security community. This will identify current technology gaps against the defence and security requirement and will inform future investments.

Early project outcomes indicate that complete telexistence systems are being developed and demonstrated in environments relevant to their respective use cases. These systems have predominantly been developed for research purposes and thus are laboratory based, but there are examples of use cases that are applicable to the defence and security user. Current limitations in the development of these technologies include a lack / loss of funding for future development, limited system mobility and limited haptics.

This presentation will describe the current technology position, and will provide recommendations for further development that will support the introduction of this technology into service if appropriate.

Applying the ATTA-bot (Acceptance, Trust, Tolerance, Anthropomorphism) framework to evaluate the introduction of a Logistics Robotic into Air Force 36 Squadron

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Background: The Royal Australian Air Force (RAAF) Amberley's 36 Squadron (36 SQN) recently installed a Konica Minolta MiR200 robot to automate the movement of aircraft parts between warehouse and flight line. Using the ATTA-bot (Acceptance, Trust, Tolerance, Anthropomorphism) technology adoption model, we collected and analysed the feedback from personnel working side-by-side the MiR200.

Aim: Our purpose was to assist RAAF with Robotics and Autonomous Systems and Artificial Intelligence (RAS-AI) strategic planning, highlighting how human factors impact on successful adoption. While the productivity advantages brought by autonomous technologies appear desirable to employers and investors (e.g., reduced risk of injury, cost savings, transferable skillsets development), the disruptions may be not equally tolerated by all the employees who have to work with them.

Methods: Semi-structured interviews interpreted within the ATTA-bot framework, which tracks how four key attitudes shape norms and beliefs during human-agent interaction:

- *Acceptance* (the openness to recognize the bot as legitimately belonging in the work environment, appreciating its contributions to the group);
- *Trust* (the inclination to rely on the bot and assign to it independent tasks);
- *Tolerance* (the readiness to endure any - real or just feared - displacement of social and professional relations caused by the bot);
- *Anthropomorphism* (the tendency to attribute to the bot the distinctive features of sentient beings, including animacy and sensitivity).

Results: The MiR200 generated mixed responses, raising questions for staff about the value of their work and jobs security. The personnel had little training to prepare for the robot, lacked experience in maintenance, were not consulted on how RAS-AI could be used to improve overall efficiencies. Still, the robot was perceived as a beneficial innovation experiment: the staff anthropomorphised the technology and accepted its limited abilities.

Conclusions: Our findings include: planning of human and technology resources need to consider pre- purchase, training, maintenance, review for evaluating upgrade and acquisition options. Recommendations for RAAF when planning integration of robots include: Staff Recruitment and Supervision for tech-friendly staff; professional preparation through courses and technical support; focus on culture including team cohesion and feedback opportunities; sabotage prevention; monitoring of evolving attitudes monitoring during human-robot interactions.

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Mitigating Automation Bias With Explanation

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Background: Intelligent agents are increasingly being used to support human decision-making strategies. This increasing reliance on automation may result in system misuse such as automation bias. Automation bias refers to errors in the human decision-making process caused by placing over reliance on automated decision support systems. Explanations, aimed at providing insight into the internal reasoning process of automated systems may be used to negate automation bias.

Aim: We investigated to what extent explanations could be used to reduce automation bias.

Method: We developed and implemented different models of explanations based on cognitive principles and evaluated their effect on user performance as well as automation bias in a uniquely defined instance of the Coloured Trails decision making game. The Coloured Trails game (CT) was developed as a research platform for analysing human decision-making strategies (Gal *et al*., 2005). We have exacerbated the game difficulty to simulate a stressful, demanding task environment with excessive workload, by setting a large board size of 10x10, using a colour scheme of 5 colours and enforcing a strict time limit of 3 minutes per each game. Each game involved 4 players, the human participant and 3 software agent opponents. We investigate different cohorts with different levels of explanations and assistance provided by an Intelligent Agent (IA).

Conclusion: Our results show that we have indeed been able to bias the participants and that different forms of explanations can reduce automation bias; however, they do not eliminate it completely.
However, since different types of explanations had different effects there is an indication that different types of explanations should be used to target different types of biases.

We also evaluated participant task load and trust in the IA advice among the different cohorts. In some cases, certain types of explanations have even been able to increase user trust and reduce workload significantly. We are currently further experimenting with another domain where participants are presented with a series of mammogram images and asked to estimate the risk level of the person whose mammogram they are presented with of having breast cancer through the identification of letters visible in the image (Chen and Howe, 2016).

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Development of a computational model of tactical decision making for human-AI teaming

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Background: Operations within complex tactical environments are often conducted by teams that are distributed across different platforms or locations. Team members often have to make decisions rapidly, in the presence of uncertainty regarding the location and intent of opposing forces, and the beliefs and actions of other team members. Advocates of the concept of human-AI teaming argue that AI can enhance decision effectiveness in these situations. However, to do so, the AI needs to have a model that allows it to predict what the other humans within the system are going to do. The purpose of this project is to develop such a model.

Approach: We have developed a computational model – the Multiple Goal Pursuit Model (MGPM: Ballard, et al., 2016, 2018) – that explains how people make choices amongst alternative courses of action when pursuing a set of goals. The MGPM architecture assumes that people have beliefs regarding the value of the goals that they are pursuing and the effectiveness of different actions with respect to those goals. These beliefs are updated as the person samples information from their environment, and hence change over time as a scenario unfolds (e.g., as threats emerge, or deadlines loom). In the first stage of the project, we have applied this model to a missile defence scenario, using it to describe how a team will allocate resources, balancing the competing goals of force protection and conservation of resources. We have developed a laboratory analogue of the missile defence scenario, and are running experiments to test whether the model can predict the actions that team members take.

Future Directions: Future work will examine whether the model can predict the actions that an adversary will take. The ultimate objective is to examine whether teams of human and AI agents can achieve decision superiority using information from a model of tactical decision making.

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From human-centred to *team-centred*: designing cyber-human teams for decision superiority

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Introduction

Defence operations are highly reliant on teamwork—the interdependent, collaborative efforts of two or more team members to achieve shared goals and objectives. The difficult environments in which these Defence teams operate are often marked by uncertainty, variability, risk, stress, information overload, and time pressure. Human teams making decisions under these challenging conditions are often assisted by cyber support, which may appear in a number of ways – from UAVs to "behind- closed-doors" automation and artificial intelligence (AI). While integrating AI within human Defence teams offers many benefits, the shift in allocation of responsibilities to a nonhuman member of the team needs to be carefully considered to minimise any negative consequences. Through a narrative literature review spanning multiple disciplines (e.g., human factors, aviation, emergency management, medicine, etc.) we identified two immediate opportunities to consider in the design of cyber-human teams for decision superiority.

1. AI for Individual Decision Making

Individual decision-making performance in complex, extreme environments is highly influenced by: 1) mental workload, 2) stress, and 3) expertise. Individuals perform best when their stress levels and mental workload are neither too low nor too high. Expertise impacts how an individual responds to stress and high workload, and how efficiently they perform tasks. These covert states can be observed via proxy measures of neuro- and physiological activity. AI can monitor workload and stress to keep individuals in their optimal performance zone by predicting when errors are about to occur, and reallocating tasks and adjusting the communication of information specific to that individual's expertise and ability.

2. Decision Making in Cyber-Human Teams

Many of the features of successful human teams are also implicated in optimising human-AI teaming. High-performing teams are adaptable and possess efficient team cognition, team situation awareness, and a shared understanding of team leadership, roles, and goals. To maximise the success of cyber- human teams, we posit that an AI team member needs to be capable of exhibiting these teamwork traits. Human-computer systems may be able to reduce errors of automation by ensuring that humans remain in the loop, at the centre of the design process by emphasising trust, transparency, and communication and situation awareness.

Conclusions

A human-centred approach to AI design can augment human performance rather than subsume human responsibilities. This can be achieved by providing support in a way that improves decision making outcomes beyond homogenous teams of human-only or AI-only members (Shneiderman, 2020). If the addition of an AI team member is trustworthy, transparent, and communicative, then AI can not only improve individual performance, but bolster efficient team processes to improve overall decision- making performance. An, but *team-centred* is the most promising way forward.

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Hybrid Human-AI Teaming in Real-Time Strategy Games

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Background: Effective human-AI teaming offers significant opportunities for improvements in team performance and decision-making, but also presents substantial challenges. One of the key challenges lies in understanding, defining, and mapping the problem space itself, which encompasses a broad range of intersecting and interacting domains (e.g., human-computer interaction, machine learning). Through our investigation of the literature, we identified three over-arching themes in developing hybrid teams. The first two themes are trust and transparency, which are likely to have a key role to play in informing and supporting high functioning hybrid teams and acceptability of such teams to humans. The third theme is transferability, which we define as the ability of new knowledge and processes gleaned in safe research and development environments to be applied to real-world Defence contexts. The current research program will investigate the application of these themes to the Defence context via modelling tactical conditions and hybrid teams in a Real-Time Strategy video game.

Aim: Our aim is to develop and conduct a research program, which applies the identified themes (i.e., trust, transparency, transferability) to model and evaluate concepts of human-AI teaming for Defence applications.

Method: In order to gain meaningful insight into this complex research space, we employed novel approaches to both mapping the literature landscape, surveying existing work, and developing a research framework. To address the considerable depth and scope of work, we employed an Agile method. Agile is an approach increasingly employed to enhance productivity and outcomes in the industrial and software development sectors.

Based on our Agile literature review process, we developed a research framework to serve as a superstructure for layering together individual elements of relevant research to create hybrid teaming models of increasing sophistication. Our framework aims to provide a structure for understanding the macro features of this research landscape, supporting holistic research into the acceptability of human-AI teaming to human team members and the affordances of AI team members.

We also carried out an evaluation of game environments and their potential to support hybrid teaming research with a view to transfer the resulting knowledge and processes to real-world Defence contexts. This evaluation entailed identifying appropriate warfighting scenarios that could usefully be explored in a game environment (e.g., asymmetrical swarming and layered missile defence). Given the complexity and modelling implications of the identified warfighting scenarios, our evaluation of game environments resulted in selection of the Real-Time Strategy video game StarCraft II. This environment will enable research into he identified warfighting scenarios and provide the flexibility to address a breadth of future research.

Intended Outcomes: Our presentation will canvas the current (nascent) state of the art in hybrid teaming, explore the key themes of trust, transparency, and transferability, and share the proposed research framework. In addition, we will explore the potential utility of StarCraft II as a research environment for hybrid human-AI team decision making and performance to enable practical and beneficial outcomes for real-world Defence applications.

Session 6 – Research Methods & Measurement

Building a Transdisciplinary Expert Consensus on the Neurocognitive Drivers of Performance Under Pressure: An International Delphi Study

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Background: The ability to perform optimally under pressure in dynamic, high-stakes environments is critical across many occupations, including the military, first responders, and competitive sports. However, there is little consensus on key neurocognitive factors underpinning such performance. Improving our understanding of the drivers of a performance under pressure across these multiple domains of application would help identify the more fundamental, shared mechanisms that may be targeted to provide wider-reaching and more adaptable benefits that will transfer beyond occupational contexts. Cognitive Fitness Framework (CF2; Aidman, 2017, 2020) was developed to integrate the growing evidence from the brain sciences into methods of identifying these fundamentals, developing measurement standards to assess them and interventions to influence them to optimise cognitive readiness. CF2 builds on the concepts of mental fitness (MF; Seligman, 2008) aimed at promoting a proactive notion of mental health and military cognitive readiness (CR; Grier, 2012) reflecting a broad set of performance predictors, from trainable skills to dynamic functional states and trait-like characteristics ranging from cognitive ability to attentional styles (Crameri et al., 2019). By integrating CR and MF with the growing consensus on key domains of cognitive functioning (RDoC; Morris & Cuthbert, 2012; Yücel et al., 2019), the CF2 enables neuroscience evidence to inform high performance applications.

Aim: Specific connections between the CF2 and RDoC are under investigation in our current meta-Delphi study aimed at establishing a broad expert consensus on the dimensions of cognitive fitness.

Method: In this transdisciplinary Delphi study, an international panel of experts from applied neuroscience and performance psychology, including military psychologists and elite sports professionals, are examining the established cognitive constructs from RDoC and evaluating the extent to which these constructs contribute to high cognitive performance. They are also examining the conceptual gaps in the current frameworks and proposing additional constructs to close these gaps.

Results: The study brings together the expert knowledge about performance under pressure in dynamic, high-stakes contexts from diverse disciplines (military, high-stakes civilian, sports, and applied cognitive neuroscience).

Conclusions: The study is ongoing. Its interim results will be presented, along with their implications for cognitive assessment, training and augmentation.

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A Flexible Gaming Environment for Reliably Measuring Cognitive Control

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Background: Over the last few years it has become accepted that reliable measurement of individual cognitive abilities requires participants to complete many more trials and/or to use tasks with larger effect sizes than are typical of existing cognitive batteries.

Aim: This project develops a new battery of cognitive control tests aimed at assessing high- performance under time pressure. It is implemented in a flexible Unity game engine[1] accessible online using only a web browser, with no local software installation necessary.[2] The first stage implements a 2D version used for testing and refinement. In the second stage a 3D version will be implemented and tested. All versions are first person, providing an easy upgrade path to VR and FR.

Method: Gaming mechanics (e.g., variety, feedback, rewards, and a leaderboard) are used to maintain engagement over extended and demanding testing sessions. The environment implements a variety of prominent measures of cognitive control including: single and dual n-back tasks, response inhibition (stop-signal task) and conflict tasks (e.g., Simon, Flanker and Stroop tasks), multi-tasking, and task switching. The tasks can be flexibly integrated into a coherent narrative around a room clearing scenario, with the full suite of tasks involving repeated cycles of: a) choosing one of 3 doors contingent on pervious choices (choices remembered over cycles constitute the n-back task); b) making a choice to open the door, which occasionally must be withheld when an alarm sounds (stop- signal task); c) entering a room and choosing the side on which an enemy is hiding (Stroop/Simon/Flanker tasks) based on information in a heads up display containing conflicting information (a relevant attribute on which decisions should be based, and an irrelevant attribute that is sometimes congruent and sometimes incongruent with the response corresponding to the relevant attribute) over two cycles (repeat vs. change in conflict-task tests task switching). Multi-tasking is tested by comparing versions without and with the n-back task (which requires rehearsing the last two doors entered while performing the other tasks). Two novel aspects have been included to increase effect sizes. In order to discourage strategies restricting attention to task-irrelevant information, the conflict tasks have occasional “double-shoot” trials, in which the enemy changes colour after the first response, signalling the need for a second response based on the irrelevant attribute. Second, novel tasks combinations (Stroop + Simon, Flanker + Simon) aim to produce an effect that is the sum of their constituent effects.

Results: The 2D task has been fully implemented and extensively tested by the research team, refining the feedback and reward system. A set of tutorials has been developed to enable efficient wide scale online deployment but enabling new users to engage with the game without support from researchers. An initial series of experiments will be run through Mechanical Turk to test different configurations and the number of trials required for reliable measurement different configurations of the 2D task.

Conclusions: These developments provide a promising avenue to provide efficient and reliable measurement of a range of cognitive-control abilities in a high-performance time-pressured environment.

[1] https://unity.com
[2] Conference attendees are encouraged to try it out. Visit the temporary URL http://*******dhss2020_cognitive and register an account. We recommend you complete the tutorial first before attempting the games.

Developing Psychometric Measures of Resilient Performance Capability: Acute Readiness and Army Resilience Traits Scales

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Background. Resilience is frequently viewed as a desirable attribute, but existing psychometric measures have been assessed as inappropriate for use in Australian Army. They were not developed with Australian forces, and focus more on resilient emotional and mental health: considerations are already assessed as standard. Instead, we focussed on resilient performance capability: both acute ('readiness') and over time ('trait resilience').

Military personnel are required to remain 'ready' for a diverse range of activities over long time periods; and managing force capability is a core concern for military decision makers. Typically, existing approaches for monitoring military readiness involve in-depth record-keeping of training, health and equipment maintenance, and/or data from wearable devices that can be both difficult to interpret and dependent on secure network connections. A widely-applicable, validated, and simple psychometric measure of perceived readiness would be valuable in generating rapid evaluations of current force capability from personnel. Likewise, training and development in military settings necessitate the ability to measure overall attributes that are targeted for development. Traits that mitigate the effects of stress and load on performance are highly desirable in military applications, and may be termed resilience in this context. A focus on resilience as protecting performance capability necessitated the development of a new measure for this purpose.

Aims. We developed two bespoke indicators of resilience, focusing on maintaining performance capability: the Acute Readiness in Military Monitoring Scale (ARMMS) and the Australian Army Resilience Traits Scale (AARTS). The two following studies were drawn from one large data- collection facilitated by DST and Australian Army, between August and October 2019.

Method. To develop this measure, we conducted two studies drawn from a large sample of 770 Australian military personnel divided between Exploratory Factor Analysis (EFA -n=500) and Confirmatory Factor Analysis (CFA - n=270).

Results. Developed from a bespoke pool of candidate items, the 32-item ARMMS demonstrated good model fit, and comprised nine factors: overall readiness; physical readiness; physical fatigue; cognitive readiness; cognitive fatigue; threat-challenge (i.e., emotional/coping) readiness; skills-and training readiness; group-team readiness, and equipment readiness. Readiness factors were negatively correlated with recent stress, current negative affect and distress, and positively correlated with resilience, wellbeing, current positive affect and a supervisor's rating of solider readiness.

We drew questionnaire items from the CD-RISC, the stress-mindset scale, a grit scale, a self-control scale and a brief psychological wellbeing scale. EFA generated a 25-item, five factor model for the Australian Army Resilience Traits Scale (AARTS), with good model fit indices, which were supported in the subsequent CFA. The five factors were: wellbeing (self-acceptance and mastery); coping efficacy; overcoming challenges; sustaining focus; and stress mindset – with proposed factors in spirituality and supportive relationships not forming coherent factors.

Conclusions. The development of the ARMMS facilitates a range of new research opportunities, as well as enabling quick, simple and easily-interpreted assessment of individual and group readiness in the military. The AARTS subscales showed good concurrent validity and thus may warrant further research using other populations, and seeking criterion validity with key learning outcomes and performance criteria.

Informing Future Royal Australian Navy (RAN) Operations Room Design through Field Data Collection Exercises: Lessons Learned and Future Recommendations

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Background: The Royal Australian Navy (RAN) will acquire nine Hunter Class Frigates (HCFs) to replace the ANZAC Class Frigates, providing a greater emphasis on Anti-Submarine Warfare (ASW). The HCF is derived from the UK Navy Type 26 design and will have the United States (US) Navy Aegis Combat System (CS) as its core capability.

Significant efforts to adapt the UK Navy operations room and the US Navy CS to the RAN context are being undertaken. As part of DST's contribution, the Human Systems Discipline in Weapons and Combat Systems Division is providing S&T guidance for Operations room design and CS user needs for the HCFs.

An Operations Room contains sensors, CS system components, and operators who coordinate and control warfighting activities through information exchange and system interactions. HCFs will have a hybrid RAN and US Navy CS inside a UK Operations room design, and a mix of RAN, US and UK Navy operator roles and responsibilities. This poses unique challenges to system and room optimisation.

To support the RAN, DST followed an approach derived from the ISO Standard 11064-1 Series: "Ergonomic design of control centres". ISO-11064 stipulates nine principles for the design of operations rooms. Principle 4 advises that the design of new operations rooms should be informed by a Situation Analysis of an existing operations room to provide greater understanding to system designers and enabling anticipation of operations room functions.

Australia does not possess an ASW optimised platform suitably analogous to the intended role of the HCFs. However, the Hobart Class Guided Missile Destroyers (DDGs) possess comparable features including a hybrid US Navy/RAN CS. Accordingly, DST conducted data collection onboard two DDGs to provide an indicative baseline regards the CS and the Operations Room design through RAN personnel feedback and warfighting observations. This required a broad range of data to gain the best representation of user feedback and lessons learned. In this presentation, DST will share the approach, key findings, and recommendations for similar Situation Analysis activities to inform human-centred design.

Aim: To conduct a Situation Analysis of the Hobart Class DDGs for greater understanding of operator roles and tasking, system and operator interactions, tactical employment of sensors and systems, and lessons learned to inform the design of the HCFs.

Method: DST conducted data collection onboard two DDGs, in November 2019 and March 2020, respectively. DST conducted user interviews, focus groups, questionnaires, console and functional walkthroughs, design syndicates and scenarios with Command and Combat System Operators.

Results: The success of qualitative and quantitative data collection methodologies varied, highlighting lessons for future applied Situation analysis activities in the future.

Conclusions: Collecting data from RAN crews in the operational environment provides a number of benefits, as they have recent experience using the systems and the room in which feedback is required. The Human Systems team have learned what data collection activities work well and which are less suited in such an environment. By sharing these lessons, we can improve future data collection activities for the design of future Operations Rooms.

Implementing Data Analytics to Maximise Human Performance

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Background: Data analytics is a term widely used to describe the use of mathematical methods to extract useful information from large data sets. There has been huge growth in the use and application of data analytics to people, including behavioural analytics, people analytics, medical analytics, training analytics and human performance. Commercial and research grade wearable sensors can be used to gather data which can be used for data analytics to improve the understanding of human performance and inform decision making. Wearable sensors can generally be split into those that focus on the collection and analysis of a single psychophysiological variable, and those that are multi- parameter psychophysiological monitoring devices, capable of measuring a number of biometrics.

Under the Future Workforce and Human Performance Programme, the Maximising Human Performance (MxHP) project managed by Dstl on behalf of the UK Ministry of Defence (MOD) is conducting research to provide Defence and Security personnel with validated solutions and advice on the most appropriate methods to use to enhance their physical and cognitive performance; this includes the use of data analytics.

Aim: In the long term, this work aims to predict human performance from personnel's physiological and psychological (cognitive/emotional) state. To meet this aim, Dstl in collaboration with the University of Chichester and Cervus Defence and Security Limited, as a first step, will undertake field-based measurements during an annual UK military exercise in October 2021 (Exercise Cambrian Patrol). Primary hypothesis: Can we discriminate between overall performance of individuals and teams on a Patrol Exercise using selected metrics?

Method: Exercise Cambrian Patrol is the premier patrolling event of the British Army with applications accepted from all three Services (Regular and Reserve Forces), and a variety of overseas military units. The exercise is a 60 km patrol over challenging terrain, during which teams of eight will complete a succession of stands that assess Military skills and physical and mental endurance whilst facing live enemies. The field trial will utilise a suite of wearable devices and conventional questionnaires and assessments to collect physiological, cognitive and psychophysiological parameters from 16-40 participants on a 48-hour exercise staggered start over a period of 8 days. Data from wearable devices will be integrated with cognitive and psychological measures and inputted into a HIVE database which is a bespoke data management, storage, analytics, reporting & visualisation system. HIVE will be used to produce outputs for subsequent analysis, apply machine learning algorithms or use statistical packages and then visualise results within intuitive dashboards.

Conclusions: Currently, the MOD manages human performance by setting a minimum standard that has to be achieved before individuals or teams can be deployed on operations. Planners do not have information on the level of performance individual fighting units may deliver; they have to assume that they will perform to the minimum standard. Local Commanders may know the true performance of their units and can tactically deploy fighting units to better effect. Providing Planners and Commanders with more detailed data on a unit's performance could improve effectiveness.

A Novel Gaze Processing Framework Using Crosscorrelation and Recurrence Quantification Analysis to Differentiate Expert Performances

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Background: Visual strategies of experts differ from that of novices which can be observed in distinct performance outcomes (Russell et al., 2014; Vansteenkiste, Vaeyens, Zeuwts, Philippaerts, & Lenoir, 2014). In a trial-based task, experts quickly become aware of important visual information and strategically approach the task (Brockmole, Hambrick, Windisch, & Henderson, 2008). This enables experts to produce better performance more consistently when compared to novices. Gaze theories such as contextual cueing, selective-attention, strategic gaze distribution and visual span are defined to study gaze behaviours of different skills levels. However, time series nature of gaze data and dynamic gaze analysis methods such as recurrence quantification analysis (RQA) have been sparsely explored in the analysis of expert performances.

Aim: The study presents a novel framework employing crosscorrelation and RQA to quantify systematic scanning from the temporal gaze data. We aim to discern the relationship between the degree of systematic gaze behaviour and performance of the participants in a training setting.

Method: A cohort of twenty-five individuals participated in an Unmanned Aerial Vehicle (UAV) refuelling task comprising ten trials of 2-minute duration. During the task, eye movements were recorded from a desktop mounted eye tracker. Data from first-5 trials were not considered in the current analysis, to eliminate biases due to learning effects (Brockmole et al., 2008; Newell & Rosenbloom, 1981). Coefficient of Variation (CoV) is used to establish the extent of variations observed in the task performance scores. Based on CoV individuals were split into two performance categories, elite (CoV <7.5%) and intermediate (CoV >=7.5%) (Brockmole et al., 2008).

The eye movement data was pre-processed and converted into a categorical gaze time-series, which included seven regions of interest (ROIs). To observe if individuals had developed a strategic approach and were skilful enough to apply the strategy on a regular basis the following framework is proposed:

1. The ROI labels in the gaze data were reordered based on individual's fixation interests. The labels were arranged in the order of maximum visits preserving the gaze distribution but aiming to enhance the selective-attention.
2. For each trial, the reordered gaze data was crosscorrelated with itself to observe the presence of strategic gaze distribution patterns.
3. Finally, the crosscorrelated patterns are concatenated and analysed through RQA. From RQA, recurrence rate, laminarity, entropy and determinism were estimated.

Results: Mann-Whitney U test demonstrated that the elite participants were characterised by significantly higher laminarity, entropy and determinism compared to intermediate. A Pearson's correlation between the RQA measures (laminarity, entropy and determinism) and CoV demonstrated a significant negative relationship.

Conclusions: Results indicate a strong relationship between consistency of performance and RQA metrics. The strong deterministic eye gaze patterns demonstrated by elite individuals, can be attributed to the effective gaze strategy observed in expert performances. The deterministic gaze behaviour in the current study represented compound theories of strategic distribution of gaze and selective attention.

The results provided evidence that eye gaze dynamics can be used as an objective measure of operator performance and has potential to discriminate levels of expertise.

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Predicting Resilience in the Face of Uncertainty: Who is Adapting well to COVID-19?

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Background: The world is facing an unprecedent global health pandemic with the spread of COVID-19. Hundreds of millions of people are living in various stages of lockdown and social isolation, resulting in loss of social contacts and, in many cases, jobs and financial security. Moreover, local and national economies are faltering, leading to concerns about recovery. Further compounding these concerns is the fact some locations have undergone multiple cycles of shutdown-reopen-shutdown. All of this creates great uncertainty around what life will look like tomorrow, next week, or next month. Indeed, early studies have consistently shown high levels of stress-related disorders, including anxiety, PTSD, and insomnia, secondary to COVID-19 and the related response measures. The increase in insomnia is particularly concerning, given insomnia increases the risk of developing anxiety or PTSD diagnoses 2.5-3-fold and increases the risk of developing depression by 7-fold. Stress and sleep problems also interfere with cognition, particularly decisions making. Of course, not all individuals will respond poorly to the changes associated with COVID-19. Some will show resilience to the lifestyle changes and uncertainty, and some may even take advantage of such changes to make decisions leading to improvements in sleep and mental health. Unfortunately, most current research focusing on understanding the consequences of COVID-19 focus on deficits. This project instead focuses on factors predicting resilience and relatively positive outcomes in the face of COVID-19.

Methods: We have leveraged 5 ongoing, relatively large scale, online, COVID-19 surveys by inserting questionnaires related to trait-level resilience into follow-up rounds of data collection in each survey. This allows us to collect data from an international and diverse set of individuals with both baseline (generally early in the pandemic) and follow-up (either after extended lockdown or around the time of initial reopenings). Resilience factors assessed were influenced by the Cognitive Fitness Framework1 and include: 1) self-control; 2) intolerance of uncertainty; 3) impulsivity; and 4) emotion regulation. Outcomes in most or all surveys include: a) sleep (including one survey with 90 days of daily sleep data/participant); b) circadian rhythms; c) mental health and substance use; d) adherence to lock-down and hygiene recommendations. Surveys also include unique features or samples, such as: 1) elite and sub-elite athletes in Australia and impacts on training and prepredness; 2) individuals with prior history of insomnia, and factors related to relapse/exacerbation of symptoms.

Conclusion: This study represents a unique methodological approach, whereby a series of national and international collaborations allow rapid data collection to examine the impacts of COVID-19. By embedding questionnaires into ongoing studies, we are able to leverage resources from around the world, thereby examining the impacts of COVID-19 both more broadly and more deeply than would otherwise be possible. This approach also allows for replication in multiple samples, including those focused on the general community, sleep disordered groups, and elite athletes. Finally, our focus on cognitive and psychological resilience factors is relatively unique, compared to most other COVID studies.

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Colour vs green symbology in head mounted displays - does it make a difference?

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Background: Advances in visual display and helmet mounted display (HMD) technology mean that where we previously had monochrome displays colour is now possible. Whilst colour is aesthetically pleasing it is also a strong saliency cue and can be used to draw visual attention, alter workload and generate faster response times. Incorporating colour must be done in a manner that improves performance and should only occur where a significant benefit can be shown.

Aim: To determine whether the integration of colour-enhanced symbology into a range of HMD tasks results in a significant benefit in pilot efficiency and performance.

Method: A commercially available fast jet flight model in X-Plane 11 was used to create a simulated flying task with flight-relevant visual monitoring (gauges and glitch), vigilance (identification of Hostile, Ambiguous, Friendly or Unknown (HAFU) symbols), divided attention (Continuously Computed Impact Point (CCIP) and auditory (respond to call-sign) tasks. Pilot performance for monochrome green symbology-like elements were compared with that from colour-enhanced symbology-like elements against dark backgrounds with night vision speckle and light backgrounds mimicking day flight. Performance was measured objectively via response times, accuracy and number of missed events. Testing was performed on a laptop because of COVID19 travel restrictions.

Results: 11 participants were recruited. Participation was restricted to those aged 18-60. Faster response times were recorded for colour enhanced symbology in the identification (colour: 1.81s, green: 2.57s, $p<0.001$), gauges (colour: 1.73s, green: 2.37s, $p=0.024$) and glitch (colour: 0.84s, green: 1.47s, $p=0.007$) tasks. No significant difference was observed for the CCIP or audio response times. Fewer missed events occurred for the identification (average number of missed events colour: 0.91, green: 3.32 $p<0.001$), gauges (colour: 0, green: 0.68 $p<0.001$) and glitch (colour: 0.05, green: 0.82, $p<0.001$) tasks. Accuracy, once missed events were removed, was not significant for any task. The effect of background was significant, with the light backgrounds resulting in longer response times for the identification task and increased missed events in the identification and CCIP ($p=0.021$) tasks. Audio response times were increased for dark background presentations ($p=0.009$).

Conclusions: The addition of colour-enhanced symbology produced significant improvements in pilot performance via reduced response times and fewer missed events in some tasks but not others. Colour is a highly salient cue and benefits can be maximised when it is integrated selectively. Colour-enhanced symbology alerts operators and directs visual attention to relevant area of the display more rapidly than monochrome display. It does not aid in processing of the stimuli once detected. Response time improvements are small but these may be operationally relevant in scenarios where split second improvements in responses can have significant consequences, such as low-level flight and combat. In particular, colour-enhanced symbology reduces significantly the number of missed events, which will be especially beneficial when the failure to recognise and respond to warnings can have catastrophic consequences. Further work is required to understand the impact of colour, including tailoring.

Measuring real-time cognitive load in naturalistic environments: initial pilot results from EEG systems worn under a military helmet

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Background: Soldiers are frequently required to engage in military tasks in complex, demanding environments. The accurate online monitoring of cognitive load would be of great value in ensuring optimal performance and maximising safety in such scenarios. There are three main complications: i) determining the validity of real-time measurement of cognitive load in naturalistic environments; ii) exploring whether comparable measures can be obtained through low-cost commercially available equipment; and iii) whether these measures are compatible with the standard equipment used by serving defence force personnel. The current project aims to address these questions through the measurement of established markers of cognitive processing in a real-world task, using both research-grade and commercial-grade EEG equipment paired with a military combat helmet. Initial piloting in our laboratory suggests that it is possible to obtain EEG measures with acceptable signal quality when participants are wearing a helmet. In this work in progress, we seek to examine whether this extends to online measures of cognitive workload.

Aim: We aim to compare markers of cognitive load obtained in naturalistic settings through research-grade and commercial EEG systems and to examine whether or not such systems provide reliable measures when integrated with military equipment.

Method: A sample of ten university students will complete two sessions of a memory task and a coincidental passive auditory oddball task. EEG will be recorded using either a research-grade (Brainvision Liveamp) or commercial (OpenBCI) system, placed under a military combat helmet. Resting state data will be acquired, as will on-task data while subjects move through a real-world university campus. Subjects will be given memory lists (5, 7 or 9 digits in length) to retain as they complete laps of an oval, and to report at the completion of each lap. Subjects will also listen to an ongoing passive auditory oddball stream while completing the memory task.

Event-related potentials will be calculated to measure neural responses to target and non-target tones in the oddball task, and differences between amplitudes of these between systems will be assessed through linear mixed-effects modelling. Time-frequency representations of frontal theta and posterior alpha activity will also be constructed between systems to measure working memory performance, and these will be used to predict memory outcomes. Finally, a representational similarity approach will be adopted to quantify differences in resting-state and task-related EEG between the two systems.

Implications: Online monitoring of cognitive load can be achieved in real-world environments, but signal quality may vary based on the specific device used. Comparing the utility of research-grade and off-the-shelf EEG systems with combat-style helmets will establish whether online monitoring of cognitive load during military-relevant tasks can be accurately measured and reliably implemented. This has important practical implications for the scope of research undertaken with military personnel, as well as theoretical and methodological significance in neural signal processing generally.

Delivering Human Sciences Impact for the Warfighter: Outcomes from Defence Human Sciences Symposium 2019 Panel Discussion

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Introduction. The Defence Human Sciences Symposium (DHSS) is the principal Australian forum held each year for those interested in the application of human sciences to enhance defence capability. During DHSS 2019 a facilitated Panel Discussion was convened with invited delegates from Army, Navy, Air Force, academia and DST. The discussion focused on the symposium theme of *Delivering Human Sciences Impact for the Warfighter*, and panel members and attendees were asked for their views in relation to three questions: (1) What does it mean to deliver impact for the warfighter? (2) What are the key challenges to delivering impact? (3) How can we overcome these challenges?

Aim. The aim of this paper is to summarise key issues raised by the panel and audience members during the session in response to the three questions.

Method. Panel members were formally invited by the first author to participate in the Panel Discussion. The panel was comprised of senior academics, defence scientists, and military representatives with significant experience and expertise in the human sciences. Panel members were provided with the list of questions at the time of invitation and asked to come prepared to share their responses during the session. The lead author facilitated the session during a 60 minute session in the program. In addition, audience members who were present for the Panel Discussion were provided with a copy of the questions and asked to provide written responses before, during or after the session and return them to the lead author. Panel and audience member responses (n=20) were analysed for key themes.

Results. Delivering *impact* was broadly described in terms of improving capabilities, performance, processes, technology and environmental conditions for warfighters. It was also described in terms of working with end-users to understand and deliver what they need. Key *challenges* to delivering impact included: gaining access to defence personnel for research; the ability to apply the 'best' methodology; developing domain knowledge to understand the military context, the time required to conduct research, organisational policies and constraints (e.g., posting cycles, information security), gaining buy-in from stakeholders, and some differences between science and military cultures. Suggestions for *overcoming* these challenges included: building and sustaining collaborative partnerships, greater communication and education between military stakeholders, academics and defence scientists, using more robust methodologies, increased access to and sharing of resources, and adopting a more strategic approach to prioritise human sciences research.

Conclusion. The DHSS 2019 panel discussion provided a valuable opportunity to capture views from the defence human sciences community about what it means to deliver impact for the warfighter. The discussion identified several key challenges faced by this community, as well as potential solutions to address them. The issues reported here are a snapshot from a small delegation but provide a basis for further focused discussions between human sciences researchers and military stakeholders to maximise the impact of human sciences research, particularly in the planning, execution and reporting phases. These discussions will be critical to addressing priority research gaps, enhancing defence capability, and 'achieving more together'.

So you need soldiers for your research…

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In the recently released "*More, Together. Defence Science and Technology Strategy 2030*"[1] the importance of collaborative partnerships between Defence, Academia and Industry is highlighted. Through these trusted relationships, the intent is to build an agile and innovative Defence Science and Technology enterprise to provide a strategic advantage to Australia. The Human Performance Research Network (HPRnet) is already developing these trusted relationships in the Human Performance discipline, however, additional opportunities to develop these relationships are likely in the future.

Research within the Human Performance discipline spans the entire research continuum from basic or mechanistic research through to applied or field-based research[2]. Within the Defence context, however, Human Performance research is more likely to be skewed towards applied research, and will usually require a field-based trial to ensure face validity and credibility within a Defence setting. Historically the majority of Human Performance research has been undertaken in an elite sports population in a controlled laboratory setting, and in some instances the outcomes of such research may be directly transferable to a military setting. Frequently, however, some validation and/or adjustment will be required via a Defence field trial to ensure applicability of such findings to military. In a human performance setting, this will usually necessitate participation of personnel from a relevant military unit in the field trial. This requirement will always need to be balanced with the many competing demands on military units. To determine whether a Defence field trial is required and/or feasible, two key questions need to be addressed. Is the research question relevant and applicable to the military? And is a field trial practical in a Defence operational and/or training environment?

To seek soldiers to be participants in your study, a well-designed, practical and flexible research plan that clearly outlines Defence outcomes needs to be presented to an appropriate military unit. Moreover, a common challenge in any applied research or field trial is the number of confounding variables influencing research outcomes. In a Defence setting this challenge can be amplified, but with enthusiasm, perseverance and flexibility Defence field trials can be successful. This presentation will present some personal insights into achieving successful outcomes for Defence through military field trials based upon over 10 years of personal experience in conducting Defence research including four years embedded in an operational Army unit.

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Application of Sensor Technology in Extreme Workplace Contexts

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Background: Teams working in safety-critical environments, such as the military, health care, and space operations are increasingly being required to sustain high levels of operational performance for extended periods of time, often in the face of uncertain and complex situations. There is growing interest in how psycho-physiological monitoring technologies (WPMTs) may be utilized to gain strategic advantage by inferring psychological states (e.g. fatigue, workload) related to operational performance.. The key appeal of wearable technologies is that they allow data to be collected passively and in real-time. This mitigates the risks associated with invasively disrupting operators during operations, and potentially enables real-time integration of wearables with decision-support systems (Charles & Nixon, 2019).

WPMTs (e.g., ECG, sleep trackers) are already being implemented in safety-critical industries (e.g. transport, mining) to measure employee mental states (e.g. fatigue, workload, stress) (Lohani et al., 2019). Despite this, there exists considerable doubt as to how well they actually predict internal psychological states, and workplace implementation guidelines are lacking (Dawson et al., 2014).
Moreover, many consumers, researchers and decision-makers are unaware of the assumptions underlying these technologies.

Aim: The purpose of the current research was twofold. First, to evaluate the quality, maturity, and methodological heterogeneity of applied research examining WMPTs in workplace representative tasks (e.g., simulations of complex-dynamic tasks), focusing primarily on workload. Second, to identify recommendations to guide practitioners in better understanding the constraints of applying these technologies. Ultimately, we sought to inform the extent to which WMPTs may have utility as real-time decision-aids in extreme work environments.

Method & Results: This poster-presentation will outline the results of both a conventional and systematic literature review, and a sociotechnical systems analysis. This presentation will focus on the crucial role of machine learning, which we identified as crucial to the validity of WPMTs in predicting psychological states and their use in real-time decision support systems. Issues identified include: training models in laboratory instead of workplace environments, and using small sample sizes during model training. Additionally, the sociotechnical analysis resulted in a classification system for identifying broader workplace contextual factors that need to be considered prior to WMPT implementation (e.g., contingency plans; training in statistical inference).

Conclusion: Overall, our research and reviews suggested that despite WPMTs growing popularity, the evidence supporting their direct implementation to assess operationally relevant psychological states in field settings is extremely limited. Consistent with prior research, we found many commercial devices used in industry are arguably not valid predictors of psychological states and implementing them prematurely may be riskier than not adopting them at all.

We recommend that machine learning models that WMPTs metrics are derived from be trained in workplace settings, on large diverse samples, and with consideration as to how the results provided by WPMTs will be used.

Our research concludes several practical recommendations. We provide directions for future research seeking to address the recommendations outlined in this work. A final outcome was the need to predict strategy shifts, rather than manifest psychological states, that may be linked more directly with performance.

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Resilience, adaptability and cognitive readiness in the face of COVID-19: Validating CF2 constructs as predictors of lockdown readiness and mental well-being

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Background: The COVID-19 pandemic has placed a heavy burden on governments to respond with policies which are effective yet sustainable for extended periods. Substantial burden has also been placed on Australian public to respond to these measures. The Cognitive Fitness Framework (CF2) offers a set of constructs underpinning performance in high-stakes contexts, which are also likely to drive better adjustment, behaviour augmentation, and cognitive recovery during prolonged, potentially high-risk situations, such as COVID-19. The pandemic offers a unique opportunity to examine this likelihood empirically.

Aims:

1. Validate CF2 constructs (resilience, adaptability, cognitive readiness), utilising the unique natural experiment created by COVID-19;
2. Determine the factors that facilitate positive and adaptive responses following the first wave peak and lockdown – future lockdown readiness and current mental well-being.
3. Provide initial evidence for identifying and assessing the cognitive attributes that can be targeted during periods of prolonged uncertainty, in preparation for future threats.

Method: An online survey was developed and deployed following the first wave, when the threat of a second wave and another lockdown was looming in Australia. The survey included established measures of resilience and adaptability, and newly developed measures of Cognitive Pandemic Readiness, Multidimensional Index of COVID-19 Worry, and Index of COVID-19 Impact. The survey also included measures of government trust, reactance, amorality, impulsivity and self-control, conservatism, intelligence/decision-making, and demographics (age, gender, education, income, household size, financial security, social support). A sample of the Australian population was tested via the Prolific platform (N=442, 141 NSW, 126 Victoria, & 175 Other States).

Results: Readiness to deal with another lockdown was measured by 10 items which converged into one dimension (α=. 87). The Cognitive Pandemic Readiness Scale (31 questions) converged into three factors: Household&Personal Readiness (α =.95), COVID-19 Fatigue (α=.90), and COVID-19 Resilience/Growth (α=.90). The COVID-19 Impact Questionnaire captured two aspects, Positive and Negative (15 items, αs=.87 and .85). The Multidimensional COVID-19 Worry Scale assessed four dimensions: Personal/Family Concerns (α=.85), Infrastructure/Supplies Concerns (α=.87); Economy/Liberties Concerns (α=.87) and Personal Financial Concerns (α=.85). A series of regressions were conducted predicting Readiness for 2nd Lockdown and Mental Well-being from CF2 measures, controlling for other variables.
The model predicted about 83% of variance in ***Readiness for 2nd Lockdown***. Personal&Household Readiness and gender were positive predictors; and COVID-19 Fatigue and Negative COVID-19 Impact were negative predictors. The model predicted 53% of variance in the current state of ***Mental Well-being.***
Resilience/Adaptability, Social Support, Financial Security, COVID-19 Resilience/Growth and Positive COVID-19 Impact were positive predictors and Impulsivity/Reactance/Amorality, COVID-19 Fatigue, Personal/Family Concerns, and Negative COVID-19 Impact were negative predictors.

Conclusions: The preliminary findings support the important utility of CF2 constructs (resilience, adaptability, readiness) during the unique natural experiment caused by COVID-19. In particular, Personal&Team [Household] Readiness and COVID-19 Resilience/Growth need to be targeted to facilitate positive adaptive responses. The newly developed measures possess excellent psychometric properties and offer valuable tools for assessing cognitive readiness for pandemics, pandemic impact and associated worries in and the general population. The utility of these tools for applications with Defence cohorts worth further examination.