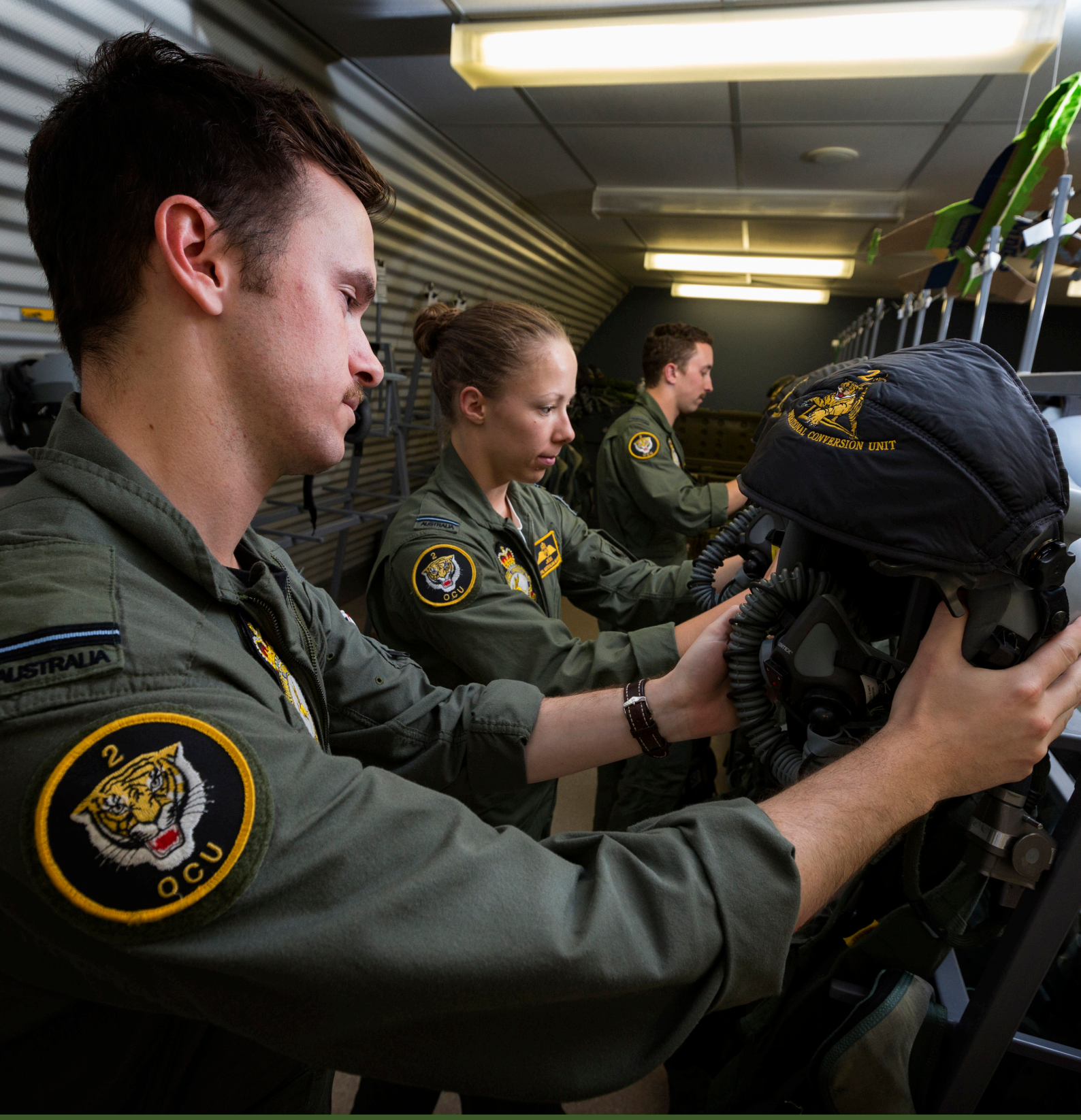


Defence Human Sciences Symposium 2021

November 29 - December 1

Australian Government
Department of Defence

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

WELCOME

The Defence Human Sciences Symposium (DHSS) has always been a highpoint in my calendar. For more years than I care to recall, it has provided the opportunity to learn more about the wide array of research that is continually revealing new ways of understanding, and meaningfully enhancing, warfighter capability.

Humans are unparalleled in their complexity. The diversity of the research community that has grown up to investigate humans and their systems is broad as a result. As a consequence, the DHSS provides a particularly rich source of creative brains capable of considering and offering innovative solutions to the rich range of opportunities and threats that military missions and environments present. The DHSS has always attracted a broad cross-section of human focused scientific disciplines and the military stakeholders keen to translate their science into capability advantage. As always, I will be looking forward to not just what has been solved by the community but also the potential solutions that will inevitably emerge from this exchange of ideas and insights.

My welcome message for last year's event looked forward to a face-to-face meeting for this year that was nearly, but not quite, possible. I am confident of achieving our aspiration for a return to an in-person symposium for 2022. More than that, we have the prospect of future events that combine the best of both worlds by delivering the opportunity for colocation and the elevation of our communication through the suite of virtual communication tools that we have become increasing proficient in applying over the last couple of years.

I would like to thank the organising committee for their commitment and flexibility in planning this event under challenging circumstances and our generous hosts, Victoria University, for their partnership in this endeavour. Finally, I would like to thank you all for taking an active part in understanding and pursuing the advantage our science and technology can deliver for the warfighter. We will achieve more, together.

Dr Nick Beagley
Research Leader Human Performance

WELCOME

Victoria University is one of only six dual-sector universities in Australia. We are uniquely positioned to offer flexible, concurrent, and complementary studies – bringing together offerings from the Polytechnic and Higher Education in the same space and time.

VU has boldly innovated a new pedagogic and curriculum approach - the VU Block Model, which has revolutionised the way tertiary education is delivered in Australia, allowing students to balance their study, work, and lives by doing just one subject at a time over a four-week period.

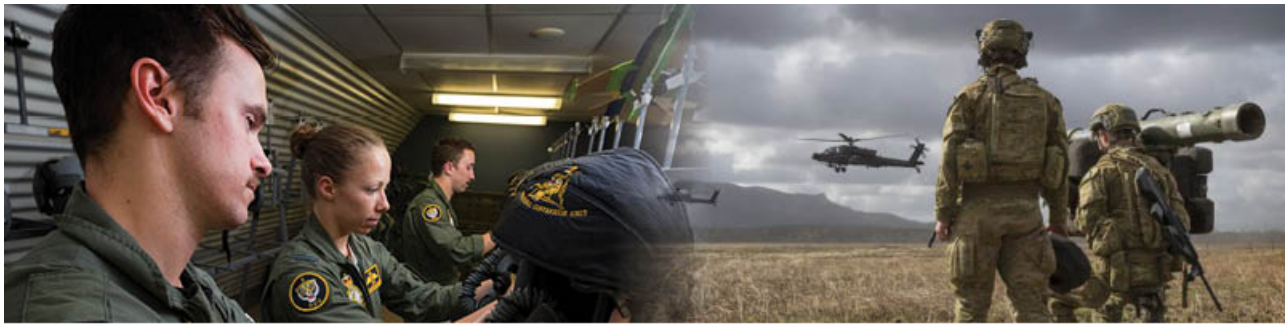
Our purpose at Victoria University is to embolden its people to design their future, with a deep commitment to Protecting Country. We support our students, colleagues, allies, partners, alumni, and friends to shape not only their own futures but also the wider world in which they live – through learning, research, career opportunities, and community and industry development. We are of the west and of the world. We have a deep and unwavering commitment to inclusion, to respectful relationships and diversity.

At Victoria University, we are committed to undertaking high-impact research that shapes healthier, smarter, and more sustainable communities across six interdisciplinary areas of research focus – including enhancing human performance by advancing and translating our understanding of bio-physical and psycho-social processes and theories. By placing our students, researchers, and external partners at the very heart of issues they are passionate about, we effect change that benefits the economy, society, and environment.

Our partnerships with community, government and industry include collaborations on research projects and programs, industry-based research training projects, joint ventures and in the commercialisation of our research.

Victoria University is proud to partner with Defence Science Technology to develop a stronger, smarter, and more innovative defence industry. I hope that the 2021 Defence Human Sciences Symposium gives you the opportunity to engage with presenters, exchange new ideas, and find innovative ways to work together.

Professor Adam Shoemaker
Vice-Chancellor and President
Victoria University



Australian Government
Department of Defence

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

Defence Human Sciences Symposium 2021 Program **Monday, 29 November**	
09:15 – 10:00	**Opening Session** Chair: Dr Nick Beagley, Defence Science and Technology Group, Department of Defence
09:15 – 09:25	**Call to Order and Housekeeping** Dr Nick Beagley, Department of Defence
09:25 – 09:30	**Welcome to Country** Gheran Yarraman Steel, The Boon Wurrung Foundation Member of the Kulin people, the Boonwurrung and Woiwurrung People, traditional owners of University land in Victoria, Victoria University
09:30 - 09:45	**Opening Remarks** Professor Tanya Monro, Chief Defence Scientist, Defence Science and Technology Group, Department of Defence
09:45 -10:00	**Opening Remarks** Professor Adam Shoemaker, Vice-Chancellor and President, Victoria University
10:00 – 14:40	**Session 1: Operating in Cyber; Information Warfare; and Chemical, Biological, Radiological, and Nuclear environments** Chair: Dr David Crone, Defence Science and Technology Group, Department of Defence
10:00 – 10:20	**Organisational Fake News: Does it Matter Who Corrects it and What They Say?** Benjamin Kropf, Kathryn Parsons and Martin Wood
10:20 – 10:40	**Countering Grey Zone Warfare Using Open-Source Intelligence to Interrupt Online Radicalisation Narratives** Carmen Jacques, Lelia Green, Kosta Lucas, Nuria Lorenzon-Dus, Lella Nouri and Daniel Baldino
10:40 – 11:00	**The Strategy of Proxy Warfare: A Framework for Operation OKRA Analysis** Andrew Maher
11:00 – 11:20	**Break**
11:20 – 11:40	**Overcoming Human Performance Challenges of Operating in CBRN Environments** Harriet Slack and Philip Temby
11:40 – 12:00	**Validating unobtrusive measures of psychological states to predict negative responses to distressing imagery for resilient human performance** Carolyn Semmler, Sau Yee Yiu, Desmond Yau, Gary Hanley, Kym Meaney, Rebecca Heyer, Sam Darvishi, Siobhan Banks, Reg Nixon and Melanie Takarangi

12:00 – 12:10	**Cognitive Biosecurity: Assessing and training perceptual expertise for Defence biosecurity threats** Matthew Thompson, Varun Gandhi, Guillermo Campitelli, Chad Hewitt, Kelly Tartano, Rebecca Ware, Shayne Loft, Richard Piola, Marnie Campbell and Zach Hambrick
12:10 – 12:20	**Towards enhancing human cognition in the cyber domain: insights from a scoping review** Benjamin Hoggan
12:20 – 12:30	**Cybersecurity behaviours under cognitive load: are you more vulnerable when you are tired?** Andrew Reeves, Dragana Pittas and Paul Delfabbro
12:30 – 13:30	**Lunch**
13:30 – 14:00	**Posters on Demand Author Q&A**
14:00 – 14:40	**Keynote Presentation** Chair: Dr David Crone, Defence Science and Technology Group, Department of Defence
14:00 – 14:40	**Defence Keynote** Commodore Andrew Quinn, Director General Surface Combatants and Aviation
14:40 – 17:00	**Session 2: Sleep + Fatigue** Chair: Prof. David Bishop, Victoria University
14:40 – 15:00	**P3R - Persistence of sleep restriction during Army basic training** Penelope Larsen, Jace Drain, Neil Gibson, John Sampson, Scott Michael, Gregory Peoples and Herbert Groeller
15:00 – 15:20	**A Smart LED Lighting System Increases Polysomnography-Derived Sleep Duration Relative to Current Lighting Conditions in Encapsulated Environments** Nicole Stuart, Jack Manners, Alisha Guyett, Hannah Scott and Peter Catcheside
15:20 – 15:40	**Understanding the dynamic relationship between fatigue and workload in submarine operations: Evidence from sea trials** Belinda Cham, Alexandra Boeing, Michael David Wilson and Karina Jorritsma
15:40 – 16:00	**Break**
16:00 – 16:10	**P3R - Exploratory Evaluation of Daily Workload and Sleep during the Infantry Initial Employment Training Course** Penny Larsen, Jace Drain, Michael Kitcher and Herbert Groeller
16:10 – 16:20	**A personalised digital sleep and circadian management tool for human performance** Tracey Sletten, Prerna Varma, Jade Murray, Michelle Magee, Lauren Booker, Sanji Kanagalingam, Svetlana Postnova, Andrew Phillips, Mark Howard and Shantha Rajaratnam
16:20 – 16:30	**The Impact of Workload, Sleep Deprivation and Time of Day on Sustained Attention** Isabella Marando, Raymond Matthews, Linda Grosser, Crystal Yates and Siobhan Banks
16:30 – 16:40	**Differential effects of sleep deprivation and sleep restriction on real-time decision error awareness** Johanna M Boardman, Zachariah R Cross, Michelle M Bravo, Thomas Andrillon, Eugene Aidman, Clare Anderson and Sean Drummond
16:40 – 16:50	**Using non-invasive brain stimulation to offset the effects of sleep deprivation** Martin Sale
16:50 – 17:00	**Combining countermeasures: napping and caffeine gum to improve performance during nightshift** Crystal Yates, Jacqueline Stepien, Jillian Dorrian, Alison Coates, Kurt Lushington, Allan Evans, Stephanie Reuter and Siobhan Banks
17:00	**End of day**

Tuesday, 30 November	
09:00 – 15:30	**Session 3: Novel interventions to improve performance** Chair: Dr Katie Tooley, Defence Science and Technology Group, Department of Defence
09:00 – 09:20	**Building a transdisciplinary expert consensus on the neurocognitive drivers of performance under pressure: An international Delphi study** Lucy Albertella, Rebecca Kirkham, Amy B. Adler, John Crampton, Sean Drummond, Gerry J. Fogarty, James J. Gross, Leonard Zaichkowsky, Eugene Aidman and Murat Yucel
09:20 – 09:40	**Improving musculoskeletal injury surveillance methods in Special Operation Forces: A Delphi consensus study** Joanne Stannard, Caroline Finch and Lauren Fortington
09:40 – 10:00	**Improving Soldier Targeting Performance Through Head and Weapon Mounted Displays** Chris Brady, Angela Bender, Sasha Quayum and Ryan Dummin
10:00 - 10:20	**Predicting team performance from neural activity: Evidence from real-world military training** Zachariah Cross, Alex Chatburn, Lee Melberzs, Philip Temby, Diane Pomeroy, Matthias Schlesewsky and Ina Bornkessel-Schlesewsky
10:20 – 10:40	**The Impact of Digital Image Configuration on Periscope Operator Workload, Situation Awareness and Performance** Steph Chen, Zach Howard, Stephen Pond, Troy Visser, Jason Bell, Gavin Pinniger, Jessica Irons, Megan Schmitt, Madison Fitzgerald, Matthew Stoker, Owen Carter, Sam Huf and Shayne Loft
10:40 – 11:00	**Dietary supplement use in the ADF: time for change?** Bianka Probert, Rosa Peterson and Bradley Baker
11:00 – 11.20	**Break**
11:20 – 11:30	**Effects of a Sports-Hydration Drink Containing High Amylose Starch on the Hydration Status and Cognitive Performance of Infantry Soldiers** Bianka Probert, Rosa Peterson and Bradley Baker
11:30 – 11:40	**Effects of combined cognitive and physical training on cognition in healthy young adults: A systematic review** Sasha Nahleen, Philip Temby, Ben Rattray, Amit Lampit and Jonathan Connor
11:40 – 11:50	**The Effect of Full Motion Video from Uninhabited Aerial Systems on Maritime Picture Compilation Task Performance** Tom Fahy and Kingsley Fletcher
11:50 – 12:00	**Integrated multi-modal evaluation of Augmented Reality information systems for active tasks** Anna Ma-Wyatt, Larissa Cahill, Dominic Thewlis, Jessica O'Rielly, Steven Wiederman, Ryan Dummin, Steven Cook, Marlon Blencowe and Edward Palmer
12:00 – 12:10	**Next generation colour displays and Laser Eye Protection: optimising both performance and safety** Amanda Douglass, Larry Abel and Maria Gavrilescu
12:10 – 12:20	**Using Weapon-Mounted Sensors for Combat Shooting Training** Jemma Coleman and Mark Biviano
12:20 – 12:30	**Investigating the benefits and costs of target detection aids** Salvatore Russo, David Nicoll, Megan Bartlett, Mike Nicholls and Oren Griffiths
12:30 – 13:30	**Lunch**
13:30 – 14:00	**Posters on Demand Author Q&A**

14:00 – 15:30	**Special session: Shaping the Defence Human Sciences Community** Chair: Dr Susannah Whitney, Defence Science and Technology Group, Department of Defence
14:00 – 14:15	**Augmenting Ability Collaborative Research Centre (CRC) update** Siobhan Banks
14:15 – 14:35	**Defence Research Ethics Review: From Compliance to a User-friendly Quality Assurance Mechanism** Lisa Headley, Warren Roberts, Kathryn Parsons, Alison Fogarty, Megan Schmitt, Angela Arvanitis, Brandon Pincombe, Christopher Best, James Brooks, Dragana Pittas, Martin Wood, Sarah Leslie, Joanne Allard, Yasmine Shaheem, Eugene Aidman
14:35 – 15:30	**Panel: Human Sciences in the time of COVID** Peta Mantel, Darrin Tyson, Susannah Whitney, Troy Visser, Vanessa Bowden and Jessica Palling
15:30 – 15:45	**Break**
15:45 - 17:35	**Session 4: R3 - resilience, readiness, recovery** Chair: Prof. Alex Parker, Victoria University
15:45 – 16:05	**A biofeedback-enabled, virtual reality, stress management training application for military trainees: From concept development to implementation** Murielle Kluge, Eugene Nalivaiko, Rohan Walker and Eugene Aidman
16:05 - `16:25	**Fostering Team Resilience via the 'STOP then Resource' Reflection Protocol: A Pilot, Non-Randomised Investigation of Feasibility Within Military Settings** Michael Chapman, Philip Temby, Lee Melberzs, Monique Crane and Daniel Gucciardi
16:25 – 16:35	**Trauma history is associated with a 1/f Electroencephalography signature in the MEAOPS combat sample** Kai Tit Tan, Andrew Lawrence, Ellie Lawrence-Wood, Suzanne Edwards, Nigel Rogasch, K Oliver Schubert, Mitchell Goldsworthy, Scott R Clark and Alexander McFarlane
16:35 – 16:45	**The Longitudinal Australian Defence Force (ADF) Study Evaluating Resilience: A summary of key findings and themes from a ten year research program evaluating resilience in early career** Lisa Dell, Carolina Casetta
16:45 – 16:55	**The Lived Experience of Psychological Contract Formation and Breach in the Australian Defence Force: An Interpretative Phenomenological Approach** Anjum Naweed, Luke Hodgkinson and Raymond Matthews
16:55 – 17:05	**Understanding Navy deployment at sea: Qualitative study of demands, resources, recovery, and resilience during maritime operations** Gavin Hazel, Monique Crane, Daniel Gucciardi and Ben Searle
17:05 – 17:15	**The Acute Readiness Monitoring Scale (ARMS): Assessing predictive and concurrent validation** Simon Summers, Richard Keegan, Andrew Flood, Kristy Martin, Andrew McKune and Ben Rattray
17:15 – 17:25	**Decision aids can improve operator resilience by enhancing learning** Oren Griffiths, Aidan Court, Sal Russo, Irina Baetu, Megan Bartlett, Gemma Robertson and Mike Nicholls
17:25	**End of day**

Wednesday, 01 December	
09:00 – 12:40	**Session 5: Characterising the environment and effects on performance** Chair: Dr Mark Patterson, Defence Science and Technology Group, Department of Defence
09:00 – 09:20	**Can communication dynamics be used to predict team cognition in command-and-control contexts?** Simon Hosking, Melissa Stolar, Patrick Watkinson, Chris Best and Dawei Jia
09:20 – 09:40	**Understanding how submariner work design relates to performance and workforce sustainability: Preliminary outcomes from a whole-of-workforce survey** Alexandra Boeing, Belinda Cham, Katrina Hosszu and Karina Jorritsma
09:40 – 10:00	**A Comparison of Overground and Treadmill Walking During Exoskeleton Assisted Load Carriage** Logan Hard, Kurt Mudie, Daniel Billing and Rezaul Begg
10:00 – 10:20	**P3R - A comprehensive analysis of injuries during Army basic military training: Do reporting methods matter?** Neil Gibson, Jace Drain, Penelope Larsen, Scott Michael, Herb Groeller and John Sampson
10:20 – 10:40	**A longitudinal exploration into the effects of 1RTB military training on aspects of cognition, well-being and diet in Australian Army recruits: Preliminary findings from the HPRnet Microbiome study** Matthew Cooke, Katie Tooley, Sarah Catchlove, Con Stough, Shakuntla Gondalia, Bradley Baker and Regina Belski
10:40 – 11:00	**Blood based biomarkers of cognitive and physical performance** Daniel Barratt, Joshua Holmes, Sanam Mustafa, Juliana Bajic, Daniel Kolarich, Nicki Packer, Ewa Goldys, Ian McKeown, Anna Ma-Wyatt, Carolyn Semmler and Mark Hutchinson
11:00 – 11.20	**Break**
11:20 – 11.30	**Recruitment into Elite Soldier Units: A Physical Readiness Study** Lisa Wolski, Alison Fogarty, Benjamin Kamphuis, Tavis Nicholson and Mark Halaki
11:30 – 11:40	**P3R — Physical and Physiological Demands of Basic Military Training** Scott Michael, Jace Drain, Penelope Larsen, Neil Gibson, Aleck MacNally and Herbert Groeller
11:40 – 11:50	**Human Intrinsic Capacity Index as a Measure of Performance in Military Science** Azmeraw Amare, Liliana Ciobanu, Beben Benyamin, Scott Clark and Renuka Visvanathan
11:50 – 12:00	**The Effect of Biological Sex on Lower-Limb Coordination Variability During Load Carriage** Brooke Hoolihan, Jon Wheat, Ben Dascombe, Danielle Vickery-Howe and Kane Middleton
12:00 – 12:10	**The Effect of Weapon Handling on Stride Time Variability** Patrick Slattery, Luis Eduardo Cofre Lizama, Jon Wheat, Paul Gastin and Kane Middleton
12:10 – 12:20	**Decision strategies: causal investigations of the trade-off between decision speed and accuracy in the frontal cortex** Hannah Filmer and Paul Dux
12:20 – 12:30	**Predicting performance on a simulated submarine control room task from discrete cognitive abilities and resting-state EEG** Chloe Dziego, Ina Bornkessel-Schlesewsky, Sophie Jano, Alex Chatburn, Matthias Schlesewsky, Maarten Immink, Ruchi Sinha, Sam Huf, Jessica Irons, Megan Schmitt, Steph Chen and Zachariah Cross

12:30 – 12:40	**Random Forest for Event Classification of Eye Movements: Towards Effective Cognitive Workload Estimation** Hadia Tazeem, Atul Sajjanhar, Tsz-Kwan Lee and Dawei Jia
12:40 – 13:40	**Lunch**
13:40 – 14:10	**Posters on Demand Author Q&A**
14:10 – 16:10	**Session 6: Human and human-machine teams** Chair: Prof Rezaul Begg, Victoria University
14:10 – 14:30	**Case Study: Ethical AI in Defence and Allied IMPACT** Dianna Gaetjens, Kate Devitt and Chris Shanahan
14:30 – 14:50	**Getting Team Members on the Same Page by Enhancing Shared Mental Models: A Systematic Review and Meta-Analysis of Controlled Trials** Daniel Gucciardi, Robin Lines, Benjamin Hoggan, Sasha Nahleen, Philip Temby and Monique Crane
14:50 – 15:10	**The Impact of Leadership Behaviors on Team Trust, Team Voice and Decision Making in the Extreme Action Teams** Ruchi Sinha, Gillian Yeo, Cecilia Tournour, Dilkash Parabia, Andrew Yu, Bart De Jong and Chia-Yen Chiu
15:10 – 15:20	**Break**
15:20 – 15:30	**Team Dynamics for Enhancing Decision-Making** Sebastian Tsui, William Tang, Yoona Choi and Wesley McTernan
15:30 – 15:40	**Modelling and monitoring human operator performance** Jessica O'Rielly, Kelli Francis-Staite, Langford White, Justin Fidock and Anna Ma-Wyatt
15:40 – 15:50	**Training and Educational Requirements of Australian Future Autonomous Ship's Operator** Gholam Reza Emad, Rachel Horne and Mehrangiz Shahbakhsh
15:50 – 16:00	**Digital Twins as a Human-Autonomy Teaming Decision Aid** Rachel Mate
16:00 – 16:10	**Designing for Agility in an Envisioned Command and Control World: Application of Cognitive Work Analysis to Human-AI Teams** Rebecca Ong and Neelam Naikar
16:10 – 16:30	**Break**
16:30 – 17:00	**Closing Session** Chair: Dr David Crone, Department of Defence
16:30 – 16:45	Presentation of awards
16:45 – 17:00	Closing remarks and thanks
17:00	**Conference end**

Posters on Demand

Monday, 29 November – Wednesday, 1 December

Theme: Sleep and Fatigue

Trait-level Cognitive and Psychological Factors Associated with Resilience to Sleep Disturbance during COVID-19
Sean Drummond, Joshua Wiley, Johanna Boardman, Tony Cunningham and Elizabeth Kensinger

The Timing of Daytime Sleep can be used Strategically to Manipulate the Response of the Internal Body Clock to Night Work
Greg Roach, Drew Dawson and Charli Sargent

The influence of variability in bed and wake times on quality of sleep in elite athletes
Shona Halson, Rich Johnston, Charli Sargent and Greg Roach

Theme: Novel interventions to improve performance

The Role of Established and Newly Proposed Cognitive Fitness Constructs in Compliance with COVID-19 Protective Measures and Psychological Recovery: A Validation Study
Sabina Kleitman, Dayna J. Fullerton, Lisa Zhang and Eugene Aidman

P3R - Impact of a pre-conditioning program on training outcomes in female Army recruits
Jace Drain, Penny Larsen and Herbert Groeller

Exploring changes in the host gut microbiota during a controlled human infection model for Campylobacter jejuni
Blake Stamps, Janelle Kuroiwa, Sandra Isidean, Megan Schilling, Clayton Harro, Kawsar Talaat, David Sack, David Tribble, Alexander Maue, Joanna Rimmer, Renee Laird, Chad Porter, Michael Goodson and Frédéric Poly

Interaction in virtual environments
Ken McAnally and Guy Wallia

The Effects of Decision Aid Presentation on Decision-Making in a Multi-Cue Signal Identification Task
Jessica Szulc, Kingsley Fletcher and Cassandra Heffernan

The effects on cognitive performance of apparel fibre type and task complexity
Carolyn Semmler, Amy Nielson, Charlie Scott and Sam Ropert

Artificial Intelligence based Smart Technology for Engineering Education Training
Monica Racha, Siva Chandrasekaran and Alex Stojcevski

Improving the measurement of attentional conflict resolution
Talira Kucina, Lindsay Wells, Amelia Kohl, Ian Lewis, James Sauer, Matt Palmer, Kristy de Salas and Andrew Heathcote

Future Force: Enhancing Shipbuilding Operations with Exoskeletons
Robert Trott, Chambers Annabelle, Armando Vozzo, David Hobbs and Giselle Rampersad

Augmenting military pilot training through an unobtrusive eye-tracking system
Alexander Robinson, Kyle Wilson, Mike Lenné and Mark Corbett

New shelf stable food technology to enable future feeding systems with increased resilience and performance
Roger Stanley, Lan Bui, Amir Ghandi, Ross Coad, Ky Nha Huynh and Samantha Sawyer

Theme: R3: resilience, readiness, recovery
Monitoring Recovery From Muscle Damage Caused By Training Chris James and Peter Arthur
Using Past and Present Indicators of Human Workload to Explain Variance in Human Performance Zach Howard, Ami Eidels, Reilly Innes and Shayne Loft
Performance-Focused Cognitive Fitness Intervention for Athletes Affected by COVID-19 John Crampton, Jeffrey Bond, Gerry Fogarty, Tony Morris and Len Zaichkowsky
A Meta-analysis of Deployment-related Demands and Resources for Emotional Resilience, Cognitive Functioning and Job-performance in Military Personnel Monique Crane, Daniel Gucciardi, Gavin Hazel, Arian Kunzelmann, Thomas Rigotti, Ben Searle and Eyal Karin
The Role of Emotional Awareness: A Qualitative Investigation into the Resilience of Emergency Services Personnel Emily Jacobs and Richard Keegan
Risk, Resilience and Recovery: Maximising Human Health and Performance in Extreme Environments through Interdisciplinary Translational Research Paradigms Kimberley Norris, Roger Stanley, Nathan Pitchford, Steven Curnin, Graeme Zosky, Benjamin Brooks, Andy Flies, Angela Martin, Meredith Nash, Megan Woods and Sarah Basc
Theme: Characterising the environment and effects on performance
The physiological effects of weapon handling during load carriage Danielle Vickery-Howe, Jace Drain, Ben Dascombe, Anthea Clarke and Kane Middleton
Soldier neuromuscular fatigue in response to varying simulated occupational field tasks: utility of the counter movement jump and isometric mid-thigh pull Michael Macartney, Tavis Nicholson, Benjamin Kamphuis, Lisa Wolski, Alison Fogarty, Robert Dunlop, Herbert Groeller and Gregory Peoples
Gut microbiota and its neuroactive potential corelated to cognitive functions in the healthy elderly adults Mrudhula Komanduri, Con Stough and Shakuntla Gondalia
Mechanisms of vigilance loss: Sensitivity decrements less robust than bias shifts and attentional lapses Shannon Gyles, Jason McCarley and Yusuke Yamani
The effect of weapon handling and walking speed on local dynamic stability of gait Luis Eduardo Cofre Lizama, Kane Middleton, Patrick Slattery and Jon Wheat
Physical and Physiological Load Monitoring in Military Settings — Opportunities and Pitfalls Scott Michael
The most discriminant components of force platform data for gait based person re-identification Kayne Duncanson, Simon Thwaites, David Booth, Gary Hanly, Ehsan Abbasnejad, William Robertson and Dominic Thewlis
Predicting real-time listener engagement from electrical brain activity: a proof-of-concept study Ashley Platt, Louise Kyriaki, Matthias Schlesewsky and Ina Bornkessel-Schlesewsky
Early detection of high risk trials during manual handling tasks using machine learning models Abdelrahman Zaroug, Alessandro Garofolini, Jasmine Proud, Daniel Lai and Rezaul Begg
Effect of exercise training programs on musculoskeletal physical fitness domains in military personnel: A systematic review and meta-analysis Chelsea Smith, Kenji Doma, Brian Heilbronn and Anthony Leicht
Towards "appreciation superiority": a set of proxy measures Luke Thiele and Philip Temby
A method to define athlete manoeuvrability in field-based team sports Grant Duthie, Sam Robertson and Heidi Thornton
Strategy use with an optimal observer aid in noisy multiple-cue judgments David Nicoll, Kingsley Fletcher, Megan Bartlett, Oren Griffiths, Mike Nicholls and Jason McCarley

Assessing lower limb running biomechanics using inertial measurement units David Opar, Kara Price, Ryan Timmins, Jack Hickey, Scott Hulm and Nirav Maniar
Semi-Active Low-profile Assistive Arm-Exoskeleton System with an Adaptive Configuration Asher Winter, Darius Nahavandi and Navid Mohajer
Expertise and Skill Learning Knowledge Can Accelerate Performance of Soldiers Sean Muller, Evan Dekker, Khaya Morris-Binelli, Benjamin Piggott, Gerard Hoyne, Zach Hambrick and Wayne Christensen
Effect of load carriage on gait variability: a case study Alessandro Garofolini, Simon Taylor and Rezaul Begg
P3R - The Whole Blood Fatty Acid Profile and the Omega-3 Index of Australian Army Recruits over the Course of Basic Military Training Gregory Peoples, Penelope Larsen, Heather Bowes, Jarrin Coombes, Jace Drain, Herbert Groeller and Peter McLennan
Reliability of Sparta Science assessments in Army personnel Anthony Leicht, Chelsea Smith, Kenji Doma, Brian Heilbronn and Jace Drain
Theme: Human and Human-Machine Teams
Autonomous Systems Reducing the Burden of Last Mile Logistics Resupply Matthew Lane, Rita Arrigo, Ben Southgate and Marceline Overduin
Conceptualising the Work Domain of Human-Machine/AI Teams in the Future Force Sheena Care and Neelam Naikar
A Closed-Loop AR-based System for Real-World BCI Application Yu-Kai Wang and Campbell Gorman

Organisational Fake News: Does it Matter Who Corrects it and What They Say?

Ben Kropf, Kathryn Parsons and Martin Wood

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Background: The Defence Strategic Update 2020 specifically refers to grey zone activity and cyber warfare as a crucial area of future research investment and capability development. Underlying this enhanced investment is an acknowledgement that the digital space has become a highly contested environment and Australia must remain agile and resilient. Recent work suggests that fabricated information or 'fake news' about organisations is likely to spread deeper and faster on social media than truths (Vosoughi, Roy & Aral, 2018). The Continued Influence Effect of misinformation often results in people continuing to rely on this fake news, despite acknowledging the presence and credibility of a correction or retraction of the fake news (Lewandowsky & van der Linden, 2021).

Aim: We explored the impact of organisational fake news and the Continued Influence Effect on customer perceptions. We also examined the role that both the source and content of the correction play in repairing these customer perceptions after fake news exposure. The influence of media skepticism and thinking style individual differences were also considered.

Method: Working Australian adults ($N = 501$) participated in the study, administered online via Qualtrics. The study used a within-subjects design to measure customer perceptions across time (i.e., pre-fake news, post-fake news and post-correction). We also incorporated a 2x2 between-subjects design at the final time point to explore the influence of both message and source manipulations on correction effectiveness. Participants were randomnly assigned to one of four possible correction conditions that were either from a Chief Executive Office (CEO) or Celebrity (source) and written in either a narrative or non-narrative style (message; Mills & Robson, 2019).

Results: Consistent with the Continued Influence Effect, results demonstrated a a significant effect across time, with customer perceptions declining significantly post-fake news exposure and rising significantly post-correction, although not to the same level as those pre-fake news exposure. The style and source of correction also affected participants.

Conclusions: Practical implications for responding to organisational misinformation are discussed. These findings have the potential to help in enhancing the resilience of Defence and Australian organisations against interference and influence in the cyber and information environments.

References:

Lewandowsky, S., & Van Der Linden, S. (2021). Countering misinformation and fake news through inoculation and prebunking. *European Review of Social Psychology*, 1-38.

Mills, A. J., & Robson, K. (2019). Brand management in the era of fake news: narrative response as a strategy to insulate brand value. *Journal of Product & Brand Management, 29(2),* 159-167.

Vosoughi, S., Roy, D., & Aral, S. (2018). The spread of true and false news online. *Science, 359*(6380), 1146-1151.

Countering Grey Zone Warfare Using Open-Source Intelligence to Interrupt Online Radicalisation Narratives

Carmen Jacques[1], Lelia Green[1], Kosta Lucas[2], Nuria Lorenzon-Dus[3], Lella Nouri[3], Daniel Baldino[4]

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Grey zone warfare (GZW) broadly refers to coercive statecraft techniques to influence change and exploit weaknesses, undertaken by state and non-state entities considered below the threshold of conventional physical (or kinetic) conflict. Campaigns can incorporate exploiting influence, interference operations and cyber threats, underpinned by the idea of 'winning without fighting'. In response to these challenges, this paper examines malign influence operations seeking to use cyber means to compromise or disrupt social cohesion, aggravate religious and racial tensions, and incite panic or animosity among political groups. It builds upon knowledge from Counter Narratives to Interrupt Online Radicalisation (CNOIR) and integrates this with research into linguistic/AI enabled profiling of online grooming/radicalisation (https://www.swansea.ac.uk/project-dragon-s/) from Swansea University's Cyber Threats Research Centre.

It argues that synergies between corpus linguistics/AI can be used to establish key markers of online radicalisation to alert Defence and focus on disrupting grey zone warfare narratives. The existing CNOIR Toolkit is ideologically neutral, comprising behaviour-focussed assessment matrices, allowing users to conduct structured professional analysis on online radicalisation trajectories of groups/individuals, based. The corpus linguistics/AI analysis allows identification of emerging threats and shifts in levels of discursive aggression, building Defence capacity and enabling nuanced 'whole-of-government' responses that are critical in threat identification and prevention. Together, these approaches integrate to form Linguistic Narrative Response (LNR). Critically, LNR research will support Defence capacity building, identifying, countering and disrupting grey zone warfare.

LNR will enable Defence Force and National Security Agencies to respond more effectively, building new knowledge around human elements of lone actors and networks promoting violent extremism and terrorism narratives online. Informed perspectives drive effective responses to (GZW) in online and offline environments. The corpus linguistics/AI analysis of large data sets support identification of actors who signal the shift from talking violence, to becoming active perpetrators, through evolving narratives and changes in discursive structure, identifying elements of anger, contempt, disgust and disregard for human life.

The Linguistics/AI methodology, successfully deployed in Project DRAGON-S, requires initial analysis of large data sets using state-of the-art, software-assisted methods in corpus linguistics. DRAGON-S datasets were provided for analysis by law enforcement as part of an exclusive data sharing agreement with the researcher and redacted prior to analysis.

Professor Nuria Lorenzo-Dus's project Developing Resistance against Grooming Online – Spotter & Shield (https://www.swansea.ac.uk/project-dragon-s/), and Swansea University's Cyber Threats Research Centre, provide expert advice for future operating environments, innovatively synergising Artificial Intelligence (Deep Learning models) and Corpus Linguistics (software assisted quantitative analysis of multi-million word data sets) methods to identify problematic discourse and establish trajectories between attitude-intention-behaviour. The proposed project would enable a specialised Defence team, interacting with AI, to sense, think and act (human performance cycle) upon violent extremist and GZW threats, contributing to an effective Defence enterprise.

The novel combination of these two methodological approaches, the CNOIR toolkit and AI/CL method (DRAGON-S) promises to deliver state of the art tools for combating violent extremism online and disrupting GZW initiatives that seek to exploit violent extremists as part of social and political destabilisation initiatives directed against democratic societies.

The Strategy of Proxy Warfare: A Framework for Operation OKRA Analysis

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Background: During the last period of major power competition – the Cold War – major powers did not deliberately engage in conflict but competed via proxy wars in peripheral areas. Proxy wars, 'the indirect engagement in a conflict by third parties wishing to influence its strategic outcome' (Mumford, 2013), are exemplified by the British support to the French Resistance in World War II and Iran's patronage of Hezbollah. Publicly-available Australian strategic policy is devoid of any exploration of proxy warfare of any kind, demonstrative of an absence of understanding within the Australian national security community. This academic gap is an issue I addressed in the Australian Strategic Policy Institute *Strategist* blog, as the gap was inhibiting the ability to craft effective strategy in the Operation OKRA context (Maher, 2017). To recognise the multi-polar competition that characterises the Middle East environment in the post-Arab Spring era is not enough; Cold War-era thinking regarding proxies needs to be evolved to the context of today's Information Age technologies and opportunities (Maher, 2018).

Aim: I contend that in today's emergent major power competition, proxy relationships are again the primary violent method for how actors compete. Understanding the strategy of proxy warfare is therefore of immediate relevance to inform Australia's national security strategy, Defence investment plan, and International Policy.

Results: Competition between major powers manifests in proxy warfare that aims to limit the risk of escalation into major war. Major, middle, and minor powers compete in this manner to impose costs on adversaries, advance their strategic objectives, and mitigating the risk of escalation into major conventional war. This research examines de-classified detainee interviews in addition to quantitative and qualitative sources to examine how actors construct proxy strategies, linking policy objectives through to tactical actions. Human decision-making heuristics compete in this environment against organisational dynamics, such as ideological orientations, alliance formation and factional politics. These human and organisational factors apply not only in the formulation of strategy, but also in the execution of proxy strategies through power-based, patron-client dynamics. In this presentation I will outline how an understanding of the proxy strategies at play can inform our analysis of the Operation OKRA intervention.

Conclusions: The significance of this research is highlighted by the Defence Strategic Update 2020. This policy document and associated funding investment was seen as the Australian Government's response to today's environment of heightened geopolitical competition. Yet, this funding and Defence planning documentation is almost exclusively orientated toward major platform acquisitions; those capabilities required for major conventional warfare (i.e. 'Respond'), and which are of much lesser utility to the land-based, irregular wars likely to arise from proxy competition (i.e. 'Shape' and 'Deter'). The potential inherent within this research is therefore one of managing risk, assuaging opportunity costs to defence policy, and opening strategic policy options to government.

References:

Maher, A. (2017), 'The war in Iraq: tactical success, strategic ambiguity,' The Strategist, Australian Strategic Policy Institute. Maher, A. (2018), 'Proxy wars and the demise of conventional warfighting,' *The Strategist*, Australian Strategic Policy Institute.
Mumford, A. (2013), *Proxy Warfare*. Cambridge, UK: Polity Press.

Overcoming Human Performance Challenges of Operating in CBRN Environments

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Background: The threat of chemical, biological, radiological and nuclear (CBRN) attacks against military forces and civilian populations is increasing [1]. In response, the ADF has articulated a need to be able to respond faster and more flexibly to CBRN events, including the ability to operate unimpeded in complex contaminated environments for prolonged periods of time [1]. The ability for humans to operate safely and effectively is made more complex by the difficulty of detecting, monitoring and containing CBRN threats. Equipping and preparing CBRN operators with innovative and effective solutions will be critical to prevailing in these environments. In support of the Operating in CBRN Environments (OCE) Science, Technology and Research Shots (STaR Shots) program, Frazer-Nash conducted a scoping study aimed at understanding human performance challenges of operating in CBRN environments and identifying potential (technology) solutions to address them.

Aim and Method: In this presentation we will outline the key findings from the scoping study which were derived from workshops with CBRN experts (n=7) and a brief literature survey. The workshops were conducted face-to-face and online using a semi-structured interview protocol and two unclassified vignettes, a Humanitarian Assistance Disaster Relief (HADR) operation and Non-combatant Evacuation Operation (NEO). Participants were asked to consider and identify relevant challenges to humans operating in these scenarios, and offer potential solutions to overcome them. Responses were qualitatively analysed for key themes in relation to challenges and possible solutions.

Results: Key challenges identified included: (1) human performance effects of wearing protective equipment including degraded physiological, sensorimotor and cognitive functioning, which may lead to poor decision-making and task performance; (2) technological constraints which limit the ability for humans to wear equipment for extended periods and move safely through contaminated areas; (3) the ability to train and educate personnel for CBRN events using realistic and cost-effective methods; (4) short- and long-term health impacts associated with exposure to CBRN threats and conducting survey and containment tasks for extended periods; and (5) interoperability challenges associated with inter-agency communication and operating procedures in response to CBRN incidents. In the presentation we will outline potential solutions for addressing these challenges which identified from the workshops and literature survey.

Conclusions: The outcomes of this study provide a basis for further work in support of efforts to enhance ADF CBRN Defence capability. Additional work is needed to explore challenges across a wider range of scenarios, and consider technology readiness levels, to more comprehensively inform development of viable solutions that may support human performance in CBRN environments.

Reference:

1. Department of Defence (n.d.). Operating in CBRN Environments STaR Shot. https://www.dst.defence.gov.au/strategy/star-shots/operating-cbrn-environments

Disclosure Statement: Frazer-Nash would like to thank the Australian Department of Defence for funding this work and the personnel who assisted with the planning and conduct of the study. The views in this document may not necessarily represent the official views of the Australian Department of Defence. The focus of this work was limited to scenarios involving chemical and biological threats.

Validating unobtrusive measures of psychological states to predict negative responses to distressing imagery for resilient human performance

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Background: Defence, intelligence and law enforcement personnel are often tasked with viewing operationally important content that can include distressing imagery. Although much research has gone into understanding the impact of direct combat engagement and threatening situations on the development of psychological problems, relatively little is known about responses to digital content. Still less has been done to understand if measures of physiological arousal that are unobtrusive, have high temporal resolution and can be deployed with minimal cost sensors, will predict negative aversive psychological states with accuracy.

Aim: The aim of the project was to assess the validity of unobtrusive sensors (video analytics) against obtrusive sensors (neurophysiology) in determining measures of negative arousal and psychological symptoms of vicarious trauma when viewing distressing video images**.**

Method: Participants included 16 healthy individuals (M_{age} = 25), with no prior history of anxiety disorders. They were exposed to 4 video segments (approximately 8 minutes in length) that had been determined to elicit negative emotion, positive emotion or a neutral state.

Data Collection Tools: Facial expression and iPPG (imaging photoplethysmography as a measure of heart rate variability) were collected via 200 fps video, 32 channel active electrodes recorded brain activity, 2 HEG (haemoencephalography) sensors placed at Fp1 and Fp2 recorded haemodynamic blood flow; all sensors were time stamped for assessment of the dynamic stress response. We also followed-up with a 7-day intrusions report using Ecological Momentary Assessment via smart phones.

Analysis Approach: We used Machine Learning approaches to classify the stress response and determine the link to reported intrusions of thoughts and images associated with the videos. We assessed frontal alpha asymmetry (FAA). This has been theorised as indicating dominance of avoidance rather than approach motivation. Alpha activity is typically measured at 8–13 Hz, and FAA is calculated as the natural log of the right minus left hemisphere. We used an Empirical Dynamic Modelling approach (Ye & Sugihara, 2016) to test the causal relationship between variables.

Results: FAA was causally related to intensity of facial expression, LF/HF HRV (low frequency/high frequency heart rate variability) ratio and subjective psychological distress, in the samples. We found relationships between the unobtrusive measures and intrusive reports. This indicates the validity of the unobtrusive measures of distress.

Conclusions: The future of defence operations, particularly those in the grey zone, will more often consist of personnel sitting in front of computer monitors well away from the forward operating areas of deployment. Understanding psychological stress and negative emotional responses to distressing content will form an important part of managing and maintaining cognitive fitness in defence personnel. The extent to which this can be automated will improve the ability of team leaders to monitor their members and ensure that they can maintain the best performance possible, with the potential for minimising the impact of psychological distress during and after deployment.

References:

Ye, H., & Sugihara, G. (2016). Information leverage in interconnected ecosystems: Overcoming the curse of dimensionality. *Science*, 353 (6302), 922-925

Cognitive Biosecurity: Assessing and training perceptual expertise for Defence biosecurity threats

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Background: The overseas deployment of naval vessels can transport non-native marine biofouling species to Australia, posing a biosecurity threat and increasing operational costs (Hewitt & Campbell, 2007). Navy rely on visual inspection of vessels above and below water to detect these threats. This is a cognitively demanding task (Thompson et al., 2014), and genuine expertise is limited (Thompson et al., 2013). As no previous research has investigated the genuine expertise of marine species identification, task proficiency in this domain is unknown, with current training based on intuition rather than evidence. The implications of incorrectly identifying biofouling species can be devastating to Australia both economically and ecologically.

Aim: In order to enhance maritime biosecurity effectiveness for naval vessels, our objectives are to: (1) Use established cognitive science approaches to develop human surveillance and detection capacities; (2) Develop measurement tools to evaluate the baseline and ongoing proficiency of surveyors; and (3) Develop effective biosecurity training materials and methods. First, we sought to answer a simple, unanswered question: how accurate are people at determining whether two species are the same or different, and does this differ as a function of expertise?

Method: We conducted two lab-based discrimination experiments on novices and experienced marine biologists and invasion ecologists. We display two images on screen, side-by-side, and ask participants to indicate whether they thought the two displayed images were of the same species or of two different species. We used photographs of various species that were sourced from a government identification guide and the web. To assess the impact of species similarity on discrimination performance, we used species taxonomy as a proxy for levels of similarity. Participants were asked to discriminate species from the same genus, family and order.

Results: We found both novice and expert participants could reliably discriminate between species above chance, at all levels of similarity. We further found that experts were significantly better than novices at discriminating between species, at all levels of similarity. Specifically looking at similarity, we found that both experts and novices were better able to discriminate between marine species that were less taxonomically similar. Thus, discrimination performance decreased as species similarity increased.

Conclusions: We found both experts and novices are able to discriminate between marine species. And taxonomic similarity impacted performance by both groups. Overall, experts performed better than novices. Our findings are consistent with other expertise studies. The findings have implications for government and citizen-science approaches to mitigating biosecurity threats. Our findings provide a foundation to design and test training tools to improve human performance in biosecurity and mitigate the threat of invasive marine species.

References:

Hewitt, C. L., & Campbell, M. L. (2007). Mechanisms for the prevention of marine bioinvasions for better biosecurity. *Marine Pollution Bulletin, 55*(7), 395-401. doi:https://doi.org/10.1016/j.marpolbul.2007.01.005

Thompson, M. B., Tangen, J. M., & McCarthy, D. J. (2013). Expertise in Fingerprint Identification. *Journal of Forensic Sciences, 58*(6), 1519-1530. doi:https://doi.org/10.1111/1556-4029.12203

Thompson, M. B., Tangen, J. M., & Searston, R. A. (2014). Understanding expertise and non-analytic cognition in fingerprint discriminations made by humans. *Frontiers in Psychology, 5*, 737. https://doi.org/10.3389/fpsyg.2014.00737

Towards enhancing human cognition in the cyber domain: insights from a scoping review

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Background: Recent change in Australia's strategic environment has seen significant investment in the cyber capabilities of the Australian Defence Force (Australian Department of Defence, 2020). Despite the cyber domain's long-held techno-centric focus, cyber professionals' psychological and cognitive abilities are fundamental to successful performance in this domain (e.g., planning, deception, sense-making, situational awareness). To date, the breadth of psychological and cognitive constructs studied in cyber professionals has not been examined in a consolidated review. Initial work to this end has been conducted by the author, with this paper building on findings presented at the previous Defence Human Sciences Symposium (Hoggan, 2020).

Aim: The overarching aim of this literature review study is to identify all empirical research that has been conducted examining the psychology and cognition of professionals in the cyber domain, to inform potential future research activities. This presentation will specifically focus on promising areas for interventions or further study identified in the review.

Method: The review followed the scoping review methodology of Arksey and O'Malley (2005), and searched empirical studies published from January 2000 to September 2020. Studies involving technological interventions to support cognition (e.g., visualisation approaches for increased situation awareness, decision-support tools) were deemed out of scope. Following removal of duplicates from the 7712 records retrieved, the abstracts of 6812 were assessed for full-text review eligibility using Research Screener (Chai et al., 2021). Of 509 articles that underwent manual full-text screening, 133 were considered relevant for inclusion in the review. Additional relevant articles were identified through author searches and reading included articles.

Results: Overall, the research identified can be characterised as being highly diverse, but equally shallow. With few exceptions, each research topic was examined in only one or two studies, and further examination or follow-up by researchers was rare. In collating and synthesising the data, studies were classified into five focus areas (in descending order of quantity of research retrieved): knowledge elicitation, influence of individual differences on cognition and performance, influence of external factors on cognition and performance, measures of cognition and aptitude, and interventions to enhance cognition and performance. It is noteworthy in the context of this presentation that fewer than 10 retrieved studies examined non-technological interventions for enhancing the cognition and related performance of cyber professionals. These studies were largely narrative, and none were of sufficient methodological quality to determine the effectiveness of the interventions described.

Conclusion: The overall body of research identified by this scoping review demonstrates a definite scientific interest in the influence that cyber professionals' psychology and cognition have on their performance. Although one might presume that substantial efforts have been made to examine how cyber professionals' cognition may be enhanced, the published literature does not support this. This makes it difficult to identify potentially high-payoff areas for intervention, investment, and further study. Inferences regarding such areas may be drawn from other areas (e.g., individual or external influences on cognition and performance), although this is complicated by limited depth of research in these areas. These issues will be discussed in the presentation.

References:

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology*, *8*(1), 19-32. https://doi.org/10.1080/1364557032000119616

Australian Department of Defence. (2020). 2020 Force Structure Plan factsheet – information and cyber. Canberra: Commonwealth of Australia. https://www1.defence.gov.au/sites/default/files/2020-11/Factsheet_Information_and_Cyber.pdf

Chai, K. E., Lines, R. L., Gucciardi, D. F., & Ng, L. (2021). Research Screener: A machine learning tool to semi-automate abstract screening for systematic reviews. *Systematic Reviews*, *10*, Article 93. https://doi.org/10.1186/s13643-021-01635-3

Hoggan, B. (2020). *Cognition research in the cyber domain: a scoping review*. Proceedings of the 2020 Defence Human Sciences Symposium (virtual event). https://www.dst.defence.gov.au/sites/default/files/events/documents/DHSS2020-Proceedings.pdf

Cybersecurity behaviours under cognitive load: are you more vulnerable when you are tired?

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Background: Predictable user passwords remain a prevalent threat to organisational cybersecurity. Despite the well-known risks, employee password behaviours continue to be poor, and this presents an opportunity for organisational psychology to offer a human perspective. Ego Depletion theory holds that performing tasks requires the use of a limited resource which, once depleted, impairs future task performance. Industry experts have suggested that employees in a cognitively depleted state will create weaker passwords than those who are cognitively alert; however, this is rarely observed in research.

Aim: This research investigated the situations in which cognitive fatigue results in diminished cybersecurity behaviours. In an attempt to unify the conflicting research space, we conducted two studies which applied best-practice recommendations from recent meta-analyses. Study 1 attempted to replicate an earlier ego depletion study relevant to the cybersecurity domain. Following unexpected results, Study 2 was developed as an iterative and constructive replication of Study 1.

Method: Four hundred and thirty-six (436) working-age adults completed the online experimental task. For Study 1, The design utilised a control group and a treatment group, who were each required to create a password for a new account. Those in the treatment group were additionally required to complete a depletion task prior to the password creation task. For increased ecological validity, participants were unaware that the password would be analysed for the study. Password strength was analysed by measuring the relevant factors of entropy, reuse, and likelihood to record. Unexpectedly, depletion did not affect password creation behaviours. Consequently, Study 2 was developed as an iterative and constructive replication of Study 1. For Study 2, we developed a novel depletion task which mimicked a real-world authentication system and required employees to perform common workplace password management behaviours. This task partially adapted the design of the well-validated 'Stroop' task and required participants to apply a series of complex rules to a password manipulation context. In addition, Study 2 applied the heuristic-systematic model (HSM) of decision making to explain the earlier null results. We hypothesised that depletion would only affect password creation behaviour when the employee is using systematic processing.

Results: Study 1 did not support the hypothesis that depletion level would predict poorer cybersecurity behaviours. However, in study 2, the novel password manipulation task successfully depleted participants and produced some expected behavioural outcomes, providing partial support for ego depletion theory and the HSM in this context. Together, the dual-study findings suggest that the relationship between an employee's level of cognitive depletion and their cybersecurity behaviour may be more nuanced than previously described in research.

Conclusions: The results suggest that depleted employees will create passwords that are less strong and secure, but only when they use systematic processing. In an applied context, these findings indicate that any positive effects of employee training may be negated if the motivated employee is fatigued at the point of password creation. Moreover, if organisational interventions succeed in motivating employees to override their poor password creation behaviours, there may be limited net benefit if the authentication system depletes them. These findings highlight the interaction between human factors and technical factors in explaining employee cybersecurity behaviour and have significant implications for the practice of cybersecurity management.

P3R - Persistence of sleep restriction during Army basic training

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Background: Considerable resources are utilised to support the training and development of recruits. A common feature of military service is reduced sleep quantity and quality in order to achieve training and operational objectives (Miller et al. 2011). However, sleep is critical for recovery from training and operational stressors. Additionally, a lack of sufficient sleep is associated with diminished physical performance, resilience, vigilance and increased risk of injury and illness. The duration of basic and trade-specific training can extend beyond six months for some soldiers before they enter the trained workforce. Therefore, the duration of exposure to sleep restriction during these foundational training phases is an important consideration, not only for training outcomes but preservation of health (Seelig et al. 2016). Sleep restriction of 6 h per night over a 2-week period has been shown to cause a similar decline in cognitive performance as two nights of total sleep deprivation (Van Dongen et al. 2003, Smith et al. 2021). Importantly, those participants that were sleep restricted had limited self-awareness of their sleepiness compared to those deprived acutely of sleep. Army mandates an 8 h sleep opportunity for recruits yet limited objective data exists of sleep duration or quality during BMT (basic military training).

Aim: To identify subjective sleep quality in young adult recruits prior to entry into BMT and objectively characterise sleep patterns, including quality and quantity, in recruits during BMT.

Method: Pittsburgh Sleep Quality Index (PSQI) was completed in the first week of training to provide a subjective estimate of Pre-BMT sleep patterns. Sleep was monitored using wrist-worn actigraphy in Australian Army recruits (n=57, 18-43y) throughout 12-weeks of BMT. Each Sunday morning accelerometers were downloaded, recharged and returned on the same day. A mixed-effects model was used to compare week-to-week and training phase (Orientation, Development, Field, Drill) differences for rates of sub-optimal sleep (6-7h), sleep restriction (≤ 6h), and actigraphy recorded sleep measures. The study was approved by the DDVA Human Research Ethics Committee (protocol number: 083-18).

Results: Recruits recorded a pre BMT global PSQI score of 5±3, sleep duration and efficiency were 7.4±1.3h and 88±9% respectively, with a sleep schedule that was highly variable; bedtime: 22:34±7:46h and wake time: 6:59±1:42h, disparate to the enforced sleep schedule within BMT. Sleep duration throughout BMT was 6.4±0.3h with all recruits recording sub-optimal sleep. Sleep restriction was present in 42% (n=24) of recruits for ≥2 consecutive weeks. In the field phase of BMT, sleep duration and efficiency declined ($p<0.01$) to 6.1±0.6h and 71±6% respectively. In contrast, sleep latency (30±15min), wake after sleep onset (121±23min), sleep fragmentation index (41±4%) and average awakening length (6.5±1.6min) were greater ($p<0.01$) than the non-field phases of BMT.

Conclusions: BMT constrained sleep schedules with observable consecutive periods of sub-optimal and restricted sleep. This sleep disruption was most prevalent during the field training phase of BMT where both quantity and quality of sleep were undermined. Consideration given to sleep hygiene and sleep extension practices may offer simple and low-cost strategies to limit sleep-associated degradation of performance during BMT.

References:

Miller NL, Shattuck LG, Matsangas P (2011). Sleep and fatigue issues in continuous operations: A survey of U.S. Army Officers. *Behavioral Sleep Medicine,* 9(1):53-65.

Seelig AD, Jacobson IG, Donoho CJ, Trone DW, Crum-Cianflone NF, Balkin TJ (2016). Sleep and Health Resilience Metrics in a Large Military Cohort. *Sleep,* 39(5):1111-1120.

Van Dongen H, Maislin G, Mullington JM, Dinges DF (2003). The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*, 26(2):117-126.

Smith MG, Wusk GC, Nasrini J, Baskin, P, Dinges, DF, Roma, PG, & Basner, MJS (2021). Effects of six weeks of chronic sleep restriction with weekend recovery on cognitive performance and wellbeing in high-performing adults. *Sleep,* https://doi.org/10.1093/sleep/zsab051.

A Smart LED Lighting System Increases Polysomnography-Derived Sleep Duration Relative to Current Lighting Conditions in Encapsulated Environments

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Background: Circadian rhythms are our internal 'body clocks' that affect the functioning of every cellular and physiological system in the body, including cognitive performance and sleep. The biggest influencer of circadian rhythms is light, but artificial lighting is typically insufficient for maintaining and adjusting circadian rhythms to be in synchrony with the desired work-sleep schedule. This issue is particularly problematic in encapsulated environments, where personnel must attempt to transition from a 'normal' schedule on land to a shift-work schedule in a dimly-lit environment. Without sufficient lighting to adjust circadian rhythms to the new schedule, sleep and cognitive performance will likely suffer.

Aim: This project tested whether a smart LED lighting system could more rapidly delay circadian rhythms to help people adjust to simulated night shift-work compared to the standard lighting levels in encapsulated environments. The current analyses tested whether the smart LED lighting system resulted in increased objective sleep duration compared to the standard lighting condition.

Method: This is a preliminary analysis of an ongoing within-subject experimental study. Healthy good sleepers (N=6) underwent two 8-day experimental conditions (smart LED lighting versus standard lighting) in the sleep laboratory, one month apart. After baseline testing on days 1 and 2, the lighting interventions began on day 3 as participants' schedules were adjusted to working at night and sleeping during the day. During the daytime sleep opportunities on days 4-7, participants were monitored via polysomnography (PSG) sleep recording.

Results: Compared to the standard lighting condition, the smart LED lighting condition produced substantially longer PSG sleep durations across the daytime sleep opportunities (*Mean Difference* = 28.23 minutes, *SE* = 20.03), although it is not a significant difference at the current sample size, $F = 1.98$, $p = .18$. Day by day, the difference in PSG sleep duration between the two lighting conditions continued to increase to a large but currently not significant difference between lighting conditions on the final day (*Mean Difference* = 72.60 minutes, *SE* = 40.12), $p = .09$.

Conclusions: When adjusting to a night shift-work schedule, smart LED lighting seems to rapidly improve sleep in a matter of days compared to current lighting in encapsulated environments, noting that a larger sample will be required before definitive statements can be made. Potential improvements on other health outcomes and cognitive performance under smart LED lighting conditions will be explored in future analyses.

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Keywords: sleep, lighting, circadian rhythms.

Understanding the dynamic relationship between fatigue and workload in submarine operations: Evidence from sea trials

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Background: Crew endurance is important enabler of Australia's submarine capability. Endurance is the capability to sustain performance for safe and effective operations over variable timeframes, ranging from a watch to an entire mission (Cham et al., 2021). A well-established indicator of endurance is mental fatigue as it has a significant negative impact on task performance (Miller et al., 2008; Shattuck et al., 2018).

In defence and similar highly-demanding settings (e.g., 24-hour operations such as offshore platforms, aviation, space), fatigue mitigation efforts have typically focused on the impact of sleep schedules, work patterns, and the influence of circadian processes (e.g., Mallis & DeRoshia, 2005; Miller et al., 2008; Riethmeister et al., 2019). However, there is growing evidence that mental fatigue can vary predictably as a function of workload (e.g., Grech et al., 2009; Wilson et al., 2021).

Workload is of particular concern in the submarine environment. Submariners experience variable and unpredictable workloads that can range from all-out response efforts that involve extreme task demands and time pressure, to long periods of monotonous/boring work. This presentation addresses the nature of both *overload* (i.e., high workload) and *underload* (i.e., low workload) as predictors of fatigue during submarine operations. We focus on the dynamic within-person relationship between workload and fatigue on a day-to-day basis.

Aim: This study is part of a larger research program seeking to understand and optimise crew endurance on the future Attack Class Submarines. The aim of the study was to understand the dynamic relationship between fatigue and workload (i.e., overload and underload) on a watch-to-watch basis over submarine operations. Examining the dynamic relationships longitudinally enables insights regarding the causal and reinforcing relationships between psychological processes across time.

Method: Three sea trials were conducted across three submarine activities during 2017-2018. A total of 76 submariners from the Royal Australian Navy participated (who varied in job role, function, and rank). We used a measurement protocol developed for the submarine environment that involved submariners filling out daily surveys for the duration of the sea trial. In the protocol, fatigue, underload, and overload were measured twice per-day (before and after each watch period).

Results and Implications: Our analysis was conducted with Dynamic Structural Equation Modelling (DSEM) in Mplus. The results showed that fatigue had a different relationship with overload relative to underload. Specifically, there was a positive bidirectional relationship with overload across time, such that overload and fatigue were mutually reinforced over multiple watch periods (e.g., a 12-hour timeframe). By contrast, there was no relationship between fatigue and underload over the same timeframe. This suggests overload induced fatigue is a greater risk underlying the development of vicious cycles of chronic fatigue that may lead to endurance degradation. Further theoretical and practical implications of these relationships will be discussed, with a focus on how the findings can inform future fatigue mitigation strategies and endurance optimisation strategies.

References:

Cham, B. S., Boeing, A. A., Wilson, M. D., Griffin, M. A., & Jorritsma, K. (2021). Endurance in extreme work environments. *Organizational Psychology Review*, doi:10.1177/20413866211006441.

Grech, M. R., Neal, A., Yeo, G., Humphreys, M., & Smith, S. (2009). An examination of the relationship between workload and fatigue within and across consecutive days of work: Is the relationshiop static or dynamic? *Journal of Occupational Health Psychology*, *14*(3), 231–242. https://doi.org/10.1037/a0014952

Mallis, M. M., & DeRoshia, C. W. (2005). Circadian rhythms, sleep, and performance in space. *Aviation Space and Environmental Medicine*, *76*(Supplement 1), 94–107.

Miller, N. L., Matsangas, P., & Shattuck, L. G. (2018). Fatigue and its effect on performance in military environments. In *Performance under stress* (pp. 247-266). CRC Press.

Wilson, M. D., Ballard, T., Strickland, L., Amy Boeing, A., Cham, B., Griffin, M. A., & Jorritsma, K. (2021). Understanding fatigue in a naval submarine: Applying biomathematical models and workload measurement in an intensive longitudinal design. *Applied Ergonomics*, *94*, 103412. https://doi.org/10.1016/j.apergo.2021.103412

Riethmeister, V., Matthews, R. W., Dawson, D., de Boer, M. R., Brouwer, S., & Bültmann, U. (2019). Time-of-day and days-on-shift predict increased fatigue over two-week offshore day-shifts. *Applied Ergonomics*, *78*, 157–163. https://doi.org/10.1016/j.apergo.2019.02.010

Shattuck, N. L., Matsangas, P., & Dahlman, A. S. (2018). Sleep and fatigue issues in military operations. In *Sleep and Combat-Related Post Traumatic Stress Disorder* (pp. 69-76). Springer, New York, NY.

P3R - Exploratory Evaluation of Daily Workload and Sleep during the Infantry Initial Employment Training Course

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Background: Physical demands, stress responses and training outcomes (physical performance, injury, attrition) associated with the Australian Army Recruit Course have been a key focus of several studies over the last two decades (Pope, Herbert et al. 1999, Booth, Probert et al. 2006, Burley, Drain et al. 2020). However, the physical demands of the Infantry Initial Employment Training (IET) course, that anecdotally is considered the most physically demanding IET within conventional Army, has yet to be examined. Furthermore, the quantity and quality of sleep, which are known to influence recovery, physical adaptation and training outcomes are also still to be investigated during Infantry IET.

Aim: Establish a preliminary understanding of the workload exposure and sleep during Infantry IET.

Method: Sixty trainees undertaking the IET course between September and November 2020 volunteered to participate in the study; 20 trainees from session 406 were monitored between weeks 1 to 8, 20 trainees from session 403 were monitored between weeks 8 to 16, and an additional 20 trainees were monitored in Holding until they commenced IET. Trainees wore wrist-mounted accelerometers (Actigraph GT9X) continuously on the non-dominant wrist. Data were recorded in 1 min epochs and analysed using Actilife v6.13.4 (ActiGraph, USA). Estimated distance (km) was calculated using the following equation: *Distance (km) = ((estimated stride length: height (cm) × 0.43) × total steps) / 100 000.*

Results: Across the entire 17-week Infantry IET course, the average daily physical activity demands were 2172 kcal, 428 min of sedentary activity, 750 min of total physical activity, 520 min of light activity, 230 min of moderate activity, no vigorous activity and ~13 km distance covered (17,882 steps). The second half of the course (weeks 8-16), which includes navigation, defence operations, offensive operations and urban operations, had higher physical demands (19% increase in estimated daily distance) and considerably greater load carriage exposure compared with weeks 1-7. The average daily sleep patterns across the IET consisted of 6.1 h total sleep time, 79% sleep efficiency, 27 awakenings, and a sleep fragmentation index of 32% per day. The longest total sleep time was 6.8 h during week 14, which followed an intensive five-week training block involving 24 h field activities and sleep restriction. Physical demands and sleep patterns during Holding were comparable to patterns during IET. There was no difference in measured physical demands between holding and the first six weeks of IET, while sleep duration (6.0 vs 6.1 h), and awakenings (28 vs 27) were similar to the mean results across the IET course.

Conclusions: Infantry trainees are exposed to moderate to high physical demands across the IET course, with only brief respite during week 7. These physical demands peak over the final nine weeks of the IET and are exacerbated by external load exposure and sleep restriction. The results from this exploratory investigation suggest limited opportunities exist for recovery from the physical demands of Infantry IET, particularly given the restricted sleep. Insufficient recovery may blunt adaptation to physical fitness training, while also increasing the risk of musculoskeletal injury and training attrition.

References:

Booth, C. K., B. Probert, C. Forbes-Ewan and R. A. Coad (2006). "Australian army recruits in training display symptoms of overtraining." Mil Med **171**(11): 1059-1064.

Burley, S. D., J. R. Drain, J. A. Sampson, B. C. Nindl and H. Groeller (2020). "Effect of a novel low volume, high intensity concurrent training regimen on recruit fitness and resilience." Journal of Science and Medicine in Sport.

Pope, R., R. Herbert, J. Kirwan and B. Graham (1999). "Predicting attrition in basic military training." Military Medicine **164**(10): 710.

A personalised digital sleep and circadian management tool for human performance

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Background: Defence personnel often work under conditions of high stress, and high cognitive and physical demand. Shift work and extended deployments can lead to sleep deprivation, circadian disruption and poor sleep quality, which combine to cause fatigue, impaired vigilance and response time, and impaired higher order cognitive functions such as tactical responses and risk-based decision making. Shift work therefore has substantial adverse impacts on deployment readiness, on-duty effectiveness and off-duty recovery. Variability in duty hours according to operational needs and individual differences in response to shift work mean that a 'one-size fits all' solution will not be effective in this complex environment. There is a need for a personalised, practical and scaleable tool that optimises sleep and circadian rhythms during periods of shift work in Defence personnel.

Aim: This project is developing an innovative evidence-based digital technology that will provide automated, personalised sleep and circadian intervention strategies to enhance recovery and optimise performance and resilience in Defence personnel.

Method: Our team has developed a prototype digital technology that is based on sleep and circadian principles. The app allows users to input information on their duty schedule, non-duty commitments and general habitual patterns. Decision tree algorithms generate biologically-driven, practical and personalised sets of recommendations to optimise sleep and recovery, including a sleep-wake schedule developed around their duty hours. Feedback on rest and recovery is continually offered to increase adherence, engage users and provide tangible behaviour change targets.

User testing of the prototype app in other shiftworking populations revealed high levels of user engagement with the app and two thirds (67%) of users reported that the app influenced their behaviour. After two weeks of app use, the majority of users reported improvements in their satisfaction with their ability to fall asleep (70%), with their quality of sleep (81%), and in their recovery during non-work periods (52%), compared to baseline. The majority of individuals also recorded improvements in scores on scales of depression, anxiety and stress.

The current project is modifying the prototype app to target sleep, performance and resilience in Defence personnel. A user-centred design process is being undertaken with representatives from the Australian Defence Force (ADF) to identify primary challenges with sleep and performance, requirements to enhance app implementation for this setting, priority features to satisfy operational demands, and the acceptability of the current app. The app will be developed to integrate user-centred design recommendations and improve the app's user experience for Defence personnel. The app will

also integrate a dynamic biomathematical model of sleep-wake dynamics, based on extensive scientific experimental studies to improve recommendations and enhance the app for variable operational situations.

The final phase of the project will evaluate, in an ADF workforce, the usability and efficacy of the app in improving sleep and performance. Participants will be randomly allocated to either: 1) the experimental group who will use the app and receive personalised sleep-wake recommendations, or 2) an active control group. Assessments will include monitoring of duty demands, sleep duration and quality, performance and daily behaviours including caffeine intake.

Conclusions: By providing personnel with the tools to self-manage their sleep and circadian behaviours, the app will empower them to be active participants in optimising their performance and resilience.

The Impact of Workload, Sleep Deprivation and Time of Day on Sustained Attention

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Abstract: Background: Sustained operations within a military setting can expose crew to work a continuous shift of more than 12 hours, with little or no breaks. These sustained operations deteriorate the ability for workers to adequately sustain attention and ultimately reduces their performance at work. Specifically, operators in a control room have the responsibility of monitoring and maintaining systems whereby faults in attention can result in devastating consequences, putting the lives of crew at risk. Biological factors, including sleep deprivation and time of day, have been shown to play a critical role in the ability to sustain attention. However, a gap in the literature exists regarding the role of external factors, such as workload. No standard universal definition of workload exists, however it has been defined as the mediating concept which reflects the task and environmental demands placed on an individual, along with their ability to meet those demands. There are multiple factors which impacts workload, including time on task.

Aim: Therefore, the aim of this study was to investigate the combined effect of sleep deprivation, time of day, and workload (time on task) on sustained attention.

Method: Twenty-one participants (18–34y, 10 F) were exposed to 62 hours of sleep deprivation within a controlled laboratory environment. Every 8 hours, sustained attention was measured using a 30-minute monotonous driving task, and subjective workload was measured using the NASA-Task Load Index (TLX). Workload, defined as time on task, was assessed by splitting the drive into two comparable 15-minute loops, with the second loop having a cumulative longer time on task. Data was analysed using a linear mixed models ANOVA.

Results: Significant main effects of day (sleep deprivation) and time of day on lane deviation, number of crashes, speed deviation and time outside the safe zone (all $p<.001$) were found. There was a significant main effect of workload (time on task) on lane deviation ($p=.042$), indicating that a longer time on task resulted in greater lane deviation. NASA-TLX scores significantly increased with sleep deprivation ($p<.001$), indicating that subjective workload increased with sleep loss even though the task remained constant.

Conclusions: Workload, sleep deprivation and time of day produced a deterioration in sustained attention, which places a large burden for control room workers within the military as they are required to attend to mundane tasks for prolonged periods at non-ideal biological times of the day. With this, countermeasures that not only consider sleep deprivation and time of day, but also workload (time on task) can be considered to reduce the performance deficits these workers may experience. This study is a steppingstone towards reducing workplace accidents and injuries of operational workers who are at the front lines of some of the most important jobs, whereby compromised performance is not an option.

Differential effects of sleep deprivation and sleep restriction on real-time decision error awareness

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Background: Sleep loss degrades cognition, cause performance errors, and increases accident and injury rates in occupational settings. Mission-critical occupations, including first responders and the military, require personnel to function and make safety-critical decisions under accumulating sleep loss, placing both the individuals and their mission at risk. The ability to detect and subsequently correct errors is therefore critical in preventing the detrimental consequences of sleep loss on performance and safety. However, it remains unclear whether sleep loss is a risk factor for errors to go unnoticed.

Aim: To investigate the impact of two types of sleep loss (total sleep deprivation [TSD] and sleep restriction [SR]) on error awareness.

Method: Thirteen healthy adults (11F, age=26.8±3.4y) underwent a 34h TSD protocol, completing the Error Awareness Task (EAT: a combined Stroop/1-back/GoNogo task) at 4h and 27h post-wake. In a separate study, twenty healthy adults (11F, age=27.4±5.3y) were studied both well-rested (WR: 9h sleep) and following SR (3 nights of 3h sleep), completing the EAT once/day (8-9h post-habitual wake). The EAT required participants to respond via a button press to "go" trials and to withhold responding to "nogo" stimuli. The participants were also instructed to press a separate button as soon as they noticed their own commission errors (i.e., failing to withhold their responses to "nogo" trials) thus enabling the measurement of both the rate and speed of error detection.

Results: We used mixed effects modelling to examine changes in (1) error rate (proportion of errors), (2) error awareness rate (proportion of errors that were detected) and (3) error awareness response time (time taken to detect errors) between WR and either TSD or SR conditions. No significant change from WR to TSD was observed for error rate ($\chi2(1)= 0.13$, $p>.05$, or error awareness rate ($\chi2(1)= 0.5$, $p>.05$), however TSD slowed error detection, with detection time significantly increasing from WR to TSD ($\chi2(1)= 8.51$, $p=.004$). In contrast, SR degraded all measures of error awareness by increasing error rate ($\chi2(1)= 23.96$, $p=<.001$), reducing error detection rates ($\chi2(1)= 28.29$, $p=<.001$), and slowing detection times ($\chi2(1)= 10.06$, $p=.002$).

Conclusions: Three nights of SR impaired both performance (more errors made compared to WR), and real time error awareness, evidenced by lower error detection rates and slower detection times. Thus, impaired error awareness may be one mechanism underlying increased sleep loss-related accidents and errors in occupational settings, and in the home. Interestingly, 1-night TSD did not lead to more errors or impair detection rates. However, TSD participants were slower to detect their own errors, which may be problematic in safety critical settings where decisions need to be made as rapidly and precisely as possible. Technological and/or operational countermeasures, such as an automated error detection system, may be needed to reduce the risk of errors going unrecognised.

Using non-invasive brain stimulation to offset the effects of sleep deprivation

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Background: In a combat environment, the ability to detect and respond to hazards faster and more accurately than your opponent is key to success. There are several brain regions involved in responding to hazards, making decisions, and learning. One key brain region is the dorsolateral prefrontal cortex (DLPFC). Unfortunately, the ability to make decisions correctly and quickly is compromised by sleep deprivation. One key component of sleep known as slow wave sleep, is characterised by low frequency, high amplitude oscillations in brain activity that assist in promoting cognitive function.

Aim: This project seeks to investigate whether the detrimental effects of sleep deprivation can be offset with non-invasive brain stimulation to mimic sleep in the awake brain.

Method: Young, healthy participants were sleep deprived for 24 hours prior to the commencement of the study. The participants then learnt a cognitive task involving learning the association between visual stimuli presented on a screen and pressing a corresponding key on a computer. Participants were divided into two groups – one group received transcranial alternating current stimulation (tACS) at a slow wave sleep frequency (0.75Hz) applied to the DLPFC and the other group received sham stimulation. Electroencephalography (EEG) recordings were also obtained to investigate the brain changes associated with the intervention.

Results: The behavioural data show that tACS following sleep deprivation increases the speed of button presses on the cognitive task compared to sham stimulation. Task accuracy remains high for both conditions. Data analysis of the EEG data are ongoing.

Conclusions: Brain stimulation can improve how quickly sleep deprived participants select a response. Given that tACS is safe, painless, cheap and portable, this approach might provide an effective means of offsetting the detrimental effects of sleep deprivation in a military context. It may therefore provide a key operational advantage in the field.

Combining countermeasures: napping and caffeine gum to improve performance during nightshift

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Background: Both naps and caffeine, a stimulant, are regularly used to mitigate performance deficits observed during sustained operations and their effectiveness in improving performance during periods of sleep deprivation have been well established. Literature on the effectiveness of combining caffeine and naps to improve performance on nightshift is lacking, although the idea of a caffeine-nap is popular with industry.

Aim: This study examined the combined impact of a nap and caffeine gum on performance, compared to napping alone during a simulated nightshift.

Method: N=7 healthy adults (18–31y; 4F) underwent two stays in the sleep laboratory one week apart with condition order randomised: condition 1) 30min nap with 200mg caffeine gum upon waking (CaffNap); and 2) a 30min nap with placebo gum upon waking (NoCaffNap). A 3min psychomotor vigilance task (PVT) and Karolinska Sleepiness Scale (KSS) were undertaken pre-nap (01:30h) and at 5, 15, 25, 35min post-nap. A 10min PVT was completed 5.5h, 3h and 1h pre-nap and 2.5h and 6.5h post-nap. PVT mean RRT and lapses were assessed.

Results: There were no significant differences for KSS or 3min PVT lapses. There was a significant condition*time effect ($p=0.032$) for 3min PVT mean RRT, such that the CaffNap condition performed significantly better post-nap. There was a significant effect of time for 10min PVT mean RRT and lapses ($p<0.001$), such that performance worsened with time spent awake. There was also a significant condition*time effect ($p=0.012$) for 10min PVT mean RRT, such that those in the CaffNap condition performed significantly better 6.5h post-nap than those in the NoCaffNap condition.

Conclusions: The combination of a 30min nap and 200mg caffeine gum improved performance during the night post-nap. Future work should investigate caffeinated gum use following longer and/ or later nap opportunities.

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 sustain optimal performance under pressure is critical across many occupations, including the military, first responders, and competitive sports. While cognitive and broader psychological factors are known to play a key role in optimal performance under pressure, how common these key performance factors are across occupations or even across application domains, remains unclear.

Aim: To integrate existing knowledge in the performance field in the form of a transdisciplinary expert consensus on the cognitive mechanisms that underlie optimal performance under pressure.

Method: International experts were recruited from four disciplines (i. Defence; ii. Competitive Sports; iii. Civilian High-stakes; and iv. Applied Cognition). They were asked to evaluate a set of constructs that included all key dimensions of cognitive functioning from the neuroscience-driven Research Domain Criteria (RDoC) framework, as well as several additional constructs that were deemed important by an expert advisory group but not covered by RDoC. Consensus was sought within each discipline using a 4-panel Delphi design. Across 3 successive rounds, experts rated (and re-rated based on emerging group data) the importance of RDoC-derived and expert-suggested constructs for optimal performance under pressure until all constructs reached consensus for inclusion or elimination. Constructs included by consensus were finally ranked for their relative importance to the four disciplines by each respective Delphi panel.

Results: Sixty-eight experts completed the first Delphi round, with 94% of experts retained by the end of the Delphi process (9-months later, the point at which consensus was reached for all panels). Seven of the ten constructs that reached consensus across all four panels came from the Cognitive Systems domain including: 1) Attention; 2) Cognitive Control—Goal Selection, Updating, Representation & Maintenance; 3) Cognitive Control—Performance Monitoring; 4) Cognitive Control—Response Selection & Inhibition/Suppression; 5) Working memory—Flexible Updating; 6) Working memory—Active Maintenance; 7) Working memory—Interference Control. Other constructs that reached consensus across all panels came from Social Processes (i.e., Self-knowledge), Arousal and Regulatory Systems (i.e., Arousal), and expert suggestions (i.e., Shifting).

Conclusions: There is clear transdisciplinary consensus on core dimensions of cognitive functioning that underpin optimal performance. Our results identify a set of neuroscience-informed constructs, validated through multi-panel Delphi consensus, that are common across human performance applications. This expert consensus is critical to standardising cognitive assessment – both for research and practical applications. It can also begin to inform more targeted and mechanism-sensitive interventions in the broader field of human performance optimisation.

Improving musculoskeletal injury surveillance methods in Special Operation Forces: A Delphi consensus study

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ABSTRACT

Background: Musculoskeletal injuries impose an extensive burden on military organisations, impacting military capability and having significant financial costs. For these reasons, injury mitigation is repeatedly stressed as an organisational and research priority to protect personnel's health and sustain a capable workforce. Despite increasing efforts to reduce injuries in the military, little attention has been given to improving the surveillance methods used to collect the necessary injury data that underpin the scientific foundations of these prevention actions. Our recent systematic review of musculoskeletal injury epidemiology in Special Operation Forces (SOF) highlighted many limitations across studies, such as inaccurate, unreliable and incomplete data collection (Stannard & Fortington, 2021). These data limitations impede the ability to inform, prioritise and evaluate injury prevention activities. Additionally, the methods used are likely to underestimate the true injury burden in these populations, compromising the accuracy of readiness information provided to commanders. A challenge in population health research, including in Defence, is defining what information is relevant to collect and how. Presently, there are no published guidelines to support effective injury surveillance in SOF. Quality improvement of surveillance methods and data standards are essential to address the current limitations.

Aim: This study aimed to identify a consensus of opinions between military injury surveillance stakeholders on data requirements and surveillance methods' relevant to SOF. Based on these consensus opinions, preliminary guidelines for injury surveillance with a view to their future use in SOF were developed.

Methods: A Delphi study was conducted with various military injury surveillance stakeholders to seek agreement on improving surveillance methods in SOF. Participants recruited included authors of recently published injury epidemiology research in SOF or conventional forces and ADF personnel with public health experience in a musculoskeletal field within Joint Health Command. Iterative online questionnaires using close and open-ended questions were used to collect views about surveillance methods related to injury case definitions and identifying essential and optional data requirements. Consensus was predefined as 75% group agreement on an item.

Results: Sixteen participants completed two rounds of questionnaires required. Most participants were researchers or clinicians with a median of 26 years of experience in their respective fields, residing across four countries. Consensus was achieved for 17.9% (n=7) of questions in the firstround and 77.5% (n=38) of round two questions. There was strong agreement in support of consistent injury surveillance methods across nations. The minimum information required to understand injuries has formed a recommended essential data set, including age, sex, employment, injury intent, place of injury occurrence, injury classification, the activity causing injury and injury mechanism. Several challenges for surveillance were identified, including recording injury causation, SOF personnel's injury reporting behaviours influencing accurate data collection, and surveillance system infrastructure limitations.

Conclusion: Key military injury surveillance stakeholders support the need for improved data collection to enhance the evidence that underpins injury prevention efforts. The basis of these recommendations can be adapted to other service populations who are likely to need similar injury surveillance requirements.

References

Stannard, J., & Fortington, L. (2021). Musculoskeletal injury in military Special Operations Forces: A systematic review. *BMJ Military Health*, bmjmilitary-2020-001692. doi:10.1136/bmjmilitary-2020-001692

Improving Soldier Targeting Performance Through Head and Weapon Mounted Displays

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Background: Project LAND 159 (Small Arms Replacement) is the Army's acquisition project to upgrade and replace much of their small arms fleet. The fleet includes rifles & pistols but also ancillaries such as weapon sights and targeting systems. New ancillary products are emerging which will take advantage of Augmented Reality (AR) displays and smart weapon sight displays (WSD). These display-based targeting aids promise to increase the speed with which a soldier can find, identify and engage a target. DSTG is conducting research with Army to understand the extent to which these new products will improve soldier lethality performance.

Aim: This study assessed the impact of several display-based target cueing aids on soldier targeting performance, including speed of engagement as compared with a baseline condition. Our research question is: to what extent do the cueing aids increase speed to detect, identify and engage?

Method: Participants completed a targeting task using different targeting aids (see table 1) within a purposebuilt scenario inside a virtual reality (VR) environment. Participants stood wearing Oculus Quest VR headsets, holding an instrumented dummy rifle linked to the VR system. Participants detected targets, then identified them as ally, neutral or enemy based on visual criteria (uniform/webbing/weapon). Participants engaged enemy targets when identified. Speed of detection, identification and engagement was recorded. Forty five participants from Lavarack Barracks participated. Soldiers also participated in focus groups at the end of their data collection sessions to discuss each aid.

Results: Detection: Both Ribbon Compass and Diamond Icons improved speed of detection over baseline, though the difference between them was minimal. Identification: Neither '% Likelihood Enemy' or 'Heads-up Sight Picture' conditions improved speed of identification over baseline. Engagement: The Heads-up Sight Picture was no faster than Baseline, and the Red Dot aid was significantly slower than the Baseline.

The Diamond icon over target was considered the best (during focus groups) for detection as it required the least amount of perceived effort from the soldier. The Ribbon Compass helped with detection but focus group feedback indicated soldiers may be confused if multiple targets are present. Trust in any AI system that generates the %-score for the "% Likelihood Enemy" Aid was an issue for many participants. Participants also reported that the % Likelihood Enemy icon draws eyes away from the target when first detected (to read the % figure) which could slow down the decision-making process. The Virtual Red Dot at maximum target distance was unusable as the reticule was the size of the target.

Conclusions:
The Diamond and Compass Lethality aids displayed on an AR HMD will speed up time to detection if they emerge as capability options for Army.

Table 1: List of Targeting Tasks and the Aids tested for each task

Targeting Task	Targeting Aids
1. Detect target	*Baseline*[1]
	Diamond
	Ribbon Compass
2. Identify target	*Baseline*
	% Likelihood Enemy
	Heads-up Sight Picture
3. Engage target*	*Baseline*
	Virtual Red Dot
*if decided target is an enemy	Heads-up Sight Picture

[1] Baseline = EF88 Rifle and Spectre DR sight with 1x and 4x zoom

Predicting team performance from neural activity: Evidence from real-world military training

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Introduction: Selecting and preparing individuals and teams to perform effectively in challenging operating environments is a priority for Defence human performance research [1]. Neuroscientific techniques can measure biomarkers of cognitive traits, thus providing valuable information about the neural dynamics of effective teams, and allocation of individuals to team roles for optimal performance. To date, limited research has examined neural markers of military team performance in real-world settings (e.g., [2, 3]).

Aims: Using state-of-the-art portable electroencephalography (EEG), the current study addressed whether (1) there are EEG-based correlates of task performance in a military context, and whether these markers track performance over time with increasing task difficulty; (2) how EEG-based correlates of task performance relate to behavioural measures (e.g., observer ratings), and; (3) whether measures of brain activity at rest predict task performance, and whether this differs based on task demands and team member role (e.g., gunner and commander)?

Methods: Forty Australian Regular Army personnel (3 female; mean age=26.34, range: 19–43) comprising 20 dyads of trained commanders and gunners from armoured and artillery regiments took part. Participants were fitted with 32-channel EEG caps and provided resting-state recording of brain activity for the measurement of intrinsic neural activity. Participants then completed three training scenarios of increasing complexity and had task-related EEG recorded throughout. Dyads completed a simulated tank gunnery or ground-based air defence (GBAD) task using in-service simulation systems. For the gunnery scenarios, task performance was assessed using the simulator output metrics, while for the GBAD scenarios, subjective ratings of performance were provided by expert trainers.

Results: Using nonlinear modelling and machine learning techniques, we found that resting-state EEG predicts performance on ecologically valid training tasks and differentiates between dyadic members. The $1/f$ slope (a measure of neural noise [4]) explained performance on more complex tasks more successfully than measures of earlier performance on an easier task ($R^2 = .43$, edf = 2.98, $F = 15.61$, $p < .001$). Further, for every 1 Hz increase in the individual alpha frequency (IAF; an index of inter-individual differences in cognitive capacity [5]), an individual had 4.46 times higher odds of being a gunner than a commander (se = .67, $p = .02$). Theta and alpha activity (neural correlates of working memory and attention, respectively [6, 7]) also increased alongside task complexity, suggesting that theta/alpha activity play a critical role in complex task performance in teams.

Conclusion: Our analyses suggest EEG can be reliably recorded from military personnel performing operationally-relevant tasks and used to quantify the likelihood of team success. We also demonstrated that resting-state measures of brain activity predict role in team situations, suggesting

that resting-state brain activity contains information relevant to team role placement. Finally, we demonstrated the utility of EEG to predict task performance above standard behavioural metrics. Our findings may be relevant in tailoring training and placement of military personnel into teams with greater likelihood of success. Further research is recommended to examine the replicability of the findings with other military samples such as ab-initio trainees and specialist trades.

References

Department of Defence (n.d). Human Performance Research network (HPRnet). Accessed 17 August, 2021, https://www.dst.defence.gov.au/sites/default/files/basic_pages/documents/HPRnet%20Information%2 02019.pdf

Diaz-Piedra, C., Sebastián, M. V. & Di Stasi, L. L. (2020). EEG theta power activity reflects workload among army combat drivers: an experimental study. *Brain Sciences 10*, 199.

Dodel, S., Cohn, J., Mersmann, J., Luu, P., Forsythe, C., & Jirsa, V. (2011, July). Brain signatures of team performance. In *International Conference on Foundations of Augmented Cognition* (pp. 288-297). Springer, Berlin, Heidelberg.

Lendner, J. D., Helfrich, R. F., Mander, B. A., Romundstad, L., Lin, J. J., Walker, M. P., ... & Knight, R. T. (2020). An electrophysiological marker of arousal level in humans. *Elife, 9*, e55092.

Grandy, T. H., Werkle-Bergner, M., Chicherio, C., Lövdén, M., Schmiedek, F., & Lindenberger, U. (2013). Individual alpha peak frequency is related to latent factors of general cognitive abilities. *Neuroimage, 79*, 10-18.

Klimesch, W. (2012). Alpha-band oscillations, attention, and controlled access to stored information. *Trends in Cognitive Sciences, 16*(12), 606-617.

Sauseng, P., Griesmayr, B., Freunberger, R., & Klimesch, W. (2010). Control mechanisms in working memory: a possible function of EEG theta oscillations. *Neuroscience & Biobehavioral Reviews, 34*(7), 1015-1022.

The Impact of Digital Image Configuration on Periscope Operator Workload, Situation Awareness and Performance

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Background: Modern submarine periscopes are moving from analog to digital, but there is a distinct lack of empirical evidence regarding the relative advantages that different digital human-machine interface concepts could provide. This limits the opportunity to innovate how the external visual environment is best displayed to support the operator. It is now possible to make use of rapid camera rotation or 360° camera footage to present a single display of the entire horizon simultaneously, and to digitize analysis tools for estimating the course and range of detected contacts. While such advancements may bring benefits, it is important to consider whether and how the human operator can use novel technologies and the differing advantage or cognitive burden they may impose.

Aim: The study aimed to compare the effectiveness of two human-machine interface (HMI) periscope concepts for supporting the operator completing simulated submarine missions. One HMI, termed "OPTIX", represented a digital adaptation of the traditional "view down a bearing" periscope format. The other, "OPTIMUS" (OPTronics IMplementation & Usability System) represented a future-looking conceptual design utilising digital technologies to display a 360° panoramic view of the horizon segmented across five panels as well as providing digitised analysis tools.

Method: Thirty-two participants undertook two scenarios in each HMI condition. Each scenario had six visual contacts (low taskload) or eight visual contacts (high taskload). Participants used the HMI tools to enter an accurate 'solution' of each contact (its range, course, and speed). Performance was defined as the difference between the entered solution location and the simulation location truth (Tactical Picture Error – TPE). Participants had two missions. The first was to photograph any rendezvous between two contacts. The second was to photograph any contact that entered a predefined 'danger sector'. We periodically paused the simulation to measure situation awareness (SA) and how well participants judged the accuracy of their solutions (meta-awareness). The participants were asked to rate their workload every five minutes. On completion, participants rated system useability.

Results: When using OPTIMUS, participants were faster to enter an initial solution and had a smaller TPE (i.e., better solutions) which compounded over time. Participant sensitivity (d') for detecting the rendezvous and danger sector events was greater when using OPTIMUS. Perceived workload was lower when using OPTIMUS and lower under conditions of low task-load. There was no difference in SA accuracy between HMIs (but lower SA accuracy for higher task-load scenarios), however participants were slower to respond to SA queries when using OPTIMUS reflecting degraded SA. Meta-awareness was also degraded with the use of OPTIMUS. There was no difference between HMIs in perceived system useability.

Conclusion: Our results provide evidence of the considerable advantage of the future-looking 360° panoramic OPTIMUS HMI, which supported faster and more accurate performance and lowered perceived workload, compared to when the same participants used OPTIX. However, SA and meta-awareness was poorer. We suggest that having continuous visual access to the 360° panorama enables the user to more effectively monitor the above water scene and detect changes in contact behaviour. However, while the OPTIMUS HMI concept holds a considerable advantage in that it can improve performance whilst reducing perceived workload, the SA and meta-awareness decrements are potentially problematic and warrant further investigation. Taken together however, the results support continued digital innovation in the submarine control room.

Dietary Supplement Use in the ADF: time for change?

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Background:
Dietary supplements are defined as "a food, food component, nutrient, or non-food compound that is purposefully ingested in addition to the habitually-consumed diet with the aim of achieving a specific health and/or performance benefit" (Maughan et al., 2018). ADF members use dietary supplements at higher rates than the general Australian population (Baker et al., 2019; Kullen et al., 2019, Probert, 2020) and likely to increase, in line with the increasing trends in use observed in military populations (Lieberman et al., 2010; Knapik et al., 2016; Baker et al., 2019; Probert, 2020).

Several dietary supplements are supported by "good to strong" evidence for enhancing aspects of performance, e.g. caffeine and creatine. Others may be recommended by Medical Practitioners or Dietitians to treat and/or prevent nutrient deficiencies e.g. iron and calcium (Maughan et al., 2018). Moreover, protein supplements and sports drinks can provide convenient sources of nutrients to enhance aspects of performance and/or recovery when it is impractical to consume everyday foods. ADF members can often experience periods of poor energy and nutrient intakes during training and deployment that may lead to compromised health and performance. Thus, to maintain a performance edge over adversaries, the use of dietary supplements that are safe, effective and appropriate should be considered, particularly when nutritional requirements cannot be met by everyday foods during training and deployment (Maughan et al., 2018).

The indiscriminate self-administration of dietary supplements can be dangerous, with many commercially available supplements linked to adverse side effects or contaminated with substances that are banned by the World Anti-Doping Agency (WADA) and/or border-controlled (LGC, 2016; Ronis et al., 2018) . Thus, increased demand for dietary supplements in the ADF, in the absence of expert guidance on their safety and efficacy, may coincide with increased prevalence of adverse side effects and members failing mandatory drug tests.
The use of health- and performance-related dietary supplements among athletes is managed by robust policies based on evidence on their safety and efficacy, however there is currently no ADF-wide system in place for providing members with access to expert guidance on dietary supplements. Moreover, it is unclear whether Defence health policies would support the prescription and supply of performance-related dietary supplements by Medical Practitioners or Accredited Sports Dietitians.

Aim: To determine whether policies developed by sporting organisations may be applicable to the future management of dietary supplement use in the ADF.

Results: Evidence related to the safety and efficacy of supplements has been translated into a robust framework by the Australian Institute of Sport (AIS), which has been used as basis by National Sporting Organisations (NSOs) to develop policies on dietary supplement use. Provision of supplements in accordance with the AIS framework has been shown to reduce the risk of individuals using contaminated products, banned substances and the misuse of potentially dangerous products. Whilst ensuring the consistent delivery of evidence based information by health professionals employed under the program (Shaw et al., 2016).

Conclusions: If developed, a bespoke ADF supplement management framework, based on those developed for athletic populations, has the potential to improve the supplement practices of ADF members by acting as an evidenced-based guidance system delivered by appropriately qualified health professionals.

Improved systems to manage supplement use in the ADF are necessary to maintain a performance edge over adversaries and reduce the risks of adverse events resulting from dietary supplement use. Engagement with a wide range of ADF health and performance stakeholders is required to understand how this may be achieved.

References:

Baker, B., Probert, B., Pomeroy, D., Carins, J., & Tooley, K. (2019). Prevalence and Predictors of Dietary and Nutritional Supplement Use in the Australian Army: A Cross-Sectional Survey. Nutrients, 11, 1462.

Kullen, C., Prvan, T., & O'Connor, H. (2019). Dietary Supplement Use in Australian Army Personnel. Military Medicine, 184(5-6), e290-e297. https://doi.org/https://dx.doi.org/10.1093/milmed/usy266

LGC. (2016). Australian Supplement Survey. Retrieved from: http://drugfreesport.org.za/wpcontent/uploads/2018/04/LGC_Australian-Supplement-Survey_0-1.pdf (accessed on 03 July 2021).

Maughan, R.J., Burke, L.M., Dvorak, J., Larson-Meyer, D.E., Peeling, P., Phillips, S.M., Rawson, E.S., Walsh, N.P., Garthe, I., Geyer, H., et al. (2018). IOC consensus statement: Dietary supplements and the high-performance athlete. British Journal of Sports Medicine, 52, 439.

Probert, B (2020). Dietary and Nutritional Supplement use in the Royal Australian Air Force. Masters Thesis, Curtin University, Western Australia.

Ronis, M. J. J., Pedersen, K. B., & Watt, J. (2018). Adverse Effects of Nutraceuticals and Dietary Supplements. Annu Rev Pharmacol Toxicol, 58(1), 583-601. https://doi.org/10.1146/annurevpharmtox-010617-052844

Shaw, G., Slater, G., & Burke, L. M. (2016). Supplement use of elite Australian swimmers. International Journal of Sport Nutrition and Exercise metabolism, 26(3), 249.

Effects of a Sports-Hydration Drink Containing High Amylose Starch on the Hydration Status and Cognitive Performance of Infantry Soldiers

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Background:
Infantry soldiers often undertake physically and cognitively demanding missions involving a variety of stressors, such as extreme climatic conditions (e.g. heat and humidity) and radical changes in diet (e.g. ration pack consumption) that can lead to poor nutrient intakes. In addition, the use of prophylactic antibiotics; which is common when training or deployed to certain locations, can lead to disturbances in gut function. Such stressors increase the risk of dehydration and the associated decrements in cognitive performance (Adam et al., 2007; Murray, 2007; Racinais et al., 2015; Tharion et al., 1997). Meta-analyses have found that a fluid losses of greater than or equal to 2% of body mass are associated with impaired physical (Goulet, 2013) and cognitive performance (Wittbrodt & Millard-Stafford, 2018). Of interest to reducing the risk of dehydration among infantry soldiers is supplementation with a combination of carbohydrate, electrolytes and high amylose maize starch
(HAMS), which has been found to optimise hydration status in both clinical (Ramakrishna et al., 2008; Ramakrishna et al., 2000) and athletic (O'Connell et al., 2018) settings.

Aim: The aim of this study was to determine the efficacy of a two stage, dual-action, hydration strategy that combines carbohydrate, electrolytes and HAMS in a beverage, compared to usual hydration practices with infantry soldiers undergoing arduous training in a tropical monsoonal climate.

Methods: A randomised crossover study was conducted at the Combat Training Centre, Jungle Training Wing, Far North Queensland, with the 7th Battalion, Royal Australian Regiment undertaking sub-unit training in October, 2019. The study was conducted over a period of 11 days during which the average daily maximum wet bulb globe temperature was 31 ºC. Participants were undertaking a varied training schedule including navigation, patrolling, webbing runs, quick attacks/ searches, ambushes, night orders and 'true grit' as part of the program. A series of assessments were performed including body mass and urine specific gravity measured before and after activities, activity monitoring, cognitive assessments and health questionnaires. Univariate analysis was conducted to determine descriptive statistics and compare study groups. Assessment of the treatment effects was performed using linear mixed effects models.

Results: The majority of participants, regardless of treatment, were experiencing dehydration of 1 to 3% fluid loss, based on body mass, across the various time points. The results indicate a trend of a reduced level of dehydration in the intervention group. Overall fluid loss (mean±SD), based on body mass (baseline minus final weight), for the intervention group (0.8±1.1%) was less than that of the control (1.5±1.4%). However, confidence with this result cannot be assured as a non-significant difference between the treatments was observed, after adjusting for confounders.

Conclusions: Infantry soldiers are at risk of dehydration, therefore strategies to promote suitable hydration behaviours are required. A significant effect of the intervention was not observed, possibly due to variability associated with real-world studies with military personnel masking any difference between the groups. It is recommended that research continue into the effectiveness of HAMS and other strategies for improved hydration status, where dehydration and suboptimal dietary intakes are at risk in the ADF.

References:

Adam, G. E., Carter, R., Cheuvront, S. N., Merullo, D. J., Castellani, J. W., Lieberman, H. R., & Sawka, M. N. (2007). Hydration effects on cognitive performance during military tasks in temperate and cold environments. Physiol Behav, 93(4), 748-756. https://doi.org/10.1016/j.physbeh.2007.11.028

Goulet, E. D. B. (2013). Effect of exercise-induced dehydration on endurance performance: evaluating the impact of exercise protocols on outcomes using a meta-analytic procedure. Br J Sports Med, 47(11), 679-686. https://doi.org/10.1136/bjsports-2012-090958

Murray, B. (2007). Hydration and physical performance. J Am Coll Nutr, 26(sup5), 542S-548S. https://doi.org/10.1080/07315724.2007.10719656

O'Connell, S. M., Woodman, R. J., Brown, I. L., Vincent, D. J., Binder, H. J., Ramakrishna, B. S., & Young, G. P. (2018). Comparison of a sports-hydration drink containing high amylose starch with usual hydration practice in Australian rules footballers during intense summer training. Journal of the International Society of Sports Nutrition, 15(1), 46. https://doi.org/10.1186/s12970-018-0253-8

Racinais, S., Alonso, J. M., Coutts, A. J., Flouris, A. D., Girard, O., González-Alonso, J., Hausswirth, C., Jay, O., Lee, J. K. W., Mitchell, N., Nassis, G. P., Nybo, L., Pluim, B. M., Roelands, B., Sawka, M. N., Wingo, J., & Périard, J. D. (2015). Consensus recommendations on training and competing in the heat. Br J Sports Med, 49(18), 1164-1173. https://doi.org/10.1136/bjsports-2015-094915

Ramakrishna, B. S., Subramanian, V., Mohan, V., Sebastian, B. K., Young, G. P., Farthing, M. J., & Binder, H. J. (2008). A randomized controlled trial of glucose versus amylase resistant starch hypo-osmolar oral rehydration solution for adult acute dehydrating diarrhea. PLoS One, 3(2), e1587-e1587. https://doi.org/10.1371/journal.pone.0001587

Ramakrishna, B. S., Venkataraman, S., Srinivasan, P., Dash, P., Young, G. P., & Binder, H. J. (2000). Amylase-resistant starch plus oral rehydration solution for Cholera. N Engl J Med, 342(5), 308-313. https://doi.org/10.1056/NEJM200002033420502

Tharion, W. J., Montain, S. J., O'Brien, C., Shippee, R. L., & Hoban, J. L. (1997). Effects of military exercise tasks and a carbohydrate-electrolyte drink on rifle shooting performance in two shooting positions. International journal of industrial ergonomics, 19(1), 31-39. https://doi.org/10.1016/0169-8141(95)00087-9

Wittbrodt, M. T., & Millard-Stafford, M. (2018). Dehydration impairs cognitive performance: a meta-analysis. Med Sci Sports Exerc, 50(11), 2360-2368. https://doi.org/10.1249/MSS.0000000000001682

Effects of combined cognitive and physical training on cognition in healthy young adults: A systematic review

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Background: Enhancing the cognitive preparation and performance of Australian Defence Force (ADF) personnel using effective and affordable training methods has been identified as a priority area for research [1]. Currently, the development of cognitive skills is achieved through on-the-job training and education. However, such training is largely dependent on job requirements and does not target the underlying cognitive capacities directly. In recent years, studies have found that combined cognitive and physical training can improve cognitive performance more than physical training alone [2, 3], leading to interest in developing multimodal training protocols for healthy adults. Given the practical benefits of using combined training, including more engaging, tailored, and time efficient training, examining the effectiveness of combined training for military personnel warrants attention.

Aim: Previous reviews on combined cognitive and physical training have focused on older and/or impaired populations [4]. To our knowledge, there has been no comprehensive systematic review of studies into the effects of combined training on cognition in healthy young adults. Therefore, the purpose of our study was to address this knowledge gap by conducting a systematic review of the published literature and synthesise the key findings and implications for future research designs.

Method: We searched MEDLINE, CINAHL, Web of Science, and PsycINFO for controlled trials examining the pre- to post-training effects of combined cognitive-physical training on cognition, compared to either cognitive or physical training alone, or a control intervention in healthy adults aged 17 to 44. Backward and forward reference searches were also conducted. In total, we found 3693 publications after duplicates were removed. All articles were screened by title, abstract and then full-text if deemed relevant. We used the Physiotherapy Evidence Database (PEDro) scale to assess the methodological quality of the studies.

Results: Nine publications (10 studies total) met our criteria. The training protocols varied greatly across experiments in relation to training length, frequency and sequence (e.g., simultaneous, separate or sequential), physical and cognitive tasks, and cognitive measures used to assess improvements over time. Two studies were of poor methodological quality and the remaining eight were of fair quality. Out of the 10 included studies, only two studies reported improved cognitive performance, specifically working memory, in the combined training group compared to all other groups.

Conclusions: Overall, we found little empirical evidence for the effectiveness of combined cognitive-physical training to enhance cognition in healthy young adults. Due to the small number of studies identified, and heterogeneity of protocols employed, robust conclusions cannot be drawn at this time. More high-quality randomised controlled trials are needed to determine the efficacy, optimal methodology, and feasibility of combined training interventions. Further, trials with military samples are needed to investigate which ADF personnel may benefit most from combined training, whether training-induced cognitive benefits transfer to job performance, and examine how to integrate new combined protocols with existing physical training policies and practices.

References

Department of Defence (n.d). Human Performance Research network (HPRnet). Accessed 02 August 2021, https://www.dst.defence.gov.au/sites/default/files/basic_pages/documents/HPRnet%20Information%2 02019.pdf

Dallaway, N., Lucas, S. J., & Ring, C. (2021). Concurrent brain endurance training improves endurance exercise performance. *Journal of Science and Medicine in Sport, 24*(4), 405-411.

Staiano, W., Merlini, M., Gattoni, C., & Marcora, S. (2019, June 1). *Impact of 4-week brain endurance training (bet) on cognitive and physical performance in professional football players* [Conference presentation]. ACSM, Orlando, FL, United States.

Lauenroth, A., Ioannidis, A. E., & Teichmann, B. (2016). Influence of combined physical and cognitive training on cognition: a systematic review. *BMC geriatrics, 16*(1), 1-14.

The Effect of Full Motion Video from Uninhabited Aerial Systems on Maritime Picture Compilation Task Performance

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Background: Maritime tactical uninhabited aerial systems (MTUAS) will be employed on future Royal Australian Navy (RAN) surface combatants. MTUAS are expected to improve RAN capability by extending and augmenting the range of ship sensors, and by providing further data to support picture compilation within the operations room. However, in order for these benefits to be fully realised, it is important that RAN crew within the operations room receive MTUAS information in a way that supports and enhances decision-making.

Aim: This study explored how the display of full motion electro-optical video, in addition to high quality still imagery, supports decision-making and workload in a picture compilation and change detection task. In particular, this research aimed to determine if full motion video supports and enhances decision-making, or encourages distraction and cognitive tunnelling.

Method: Participants were recruited from the staff and student pool within DSTG. This experiment was grounded in a picture compilation task where participants were required to identify and classify all surface contacts in an area using visual imagery from two UAVs. Visual imagery was presented in the form of still-images only, still-images plus low-quality video, and still-images plus high-quality video. As well as completing the picture compilation task, participants were required to respond to a change detection task which required participants to answer a simple math question within five seconds after it appeared on a secondary display. This task was selected to be analogous to the broader tactical scanning and decision-making tasks a PWO would be responsible for in the tactical environment in addition to assessing information from the MTUAS. Participants were informed that their performance in the picture compilation and detection response task were equally important; one task was not to be prioritised over the other. The effect of the presence and type of video imagery on picture compilation task performance and workload was examined using a repeated measures ANOVA with planned comparisons. The change detection task performance was analysed using linear mixed-effects models, which is an analysis framework that allows for analysis of nested data.

Results: This study found that the addition of both low- and high-quality full motion video from a UAV significantly reduced the time taken for participants to identify contacts compared to the no video condition. It also found that the high-quality video condition resulted in significantly faster response times to the change detection task compared to low quality video, as well as between the no-video and low-quality condition. Workload was also found to be significantly lower in the high-quality video condition compared to the no-video and low-quality video conditions.

Conclusions: Augmenting still imagery with full-motion video from MTUAS may improve picture compilation performance without degrading concurrent task performance, High quality video imagery may reduce workload and improve concurrent task performance compared to low quality video.

Integrated multi-modal evaluation of Augmented Reality information systems for active tasks

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Background:
Emerging digital display devices aim to augment the dismounted combatant's ability to operate in complex and dynamic environments via the novel presentation of information. However, these technologies present significant risk in human factors, particularly relating to perception and cognition.

In this presentation, we provide an overview of a new collaboration between Land Division and The University of Adelaide. This work is part of a Defence initiative that aims to optimise the design and application of information displays and interfaces for enhancing the performance of the dismounted combatant. The overarching objective of the research project is to define system requirements; inform acquisition decisions and assist in the development and application of technologies that will provide human-system performance benefits.

Concept:
The program of work outlined in this presentation has two aims. The first is to investigate human performance in situations analogous to those encountered by warfighters, specifically in relation to digital information displays and technologies. The second aim is to establish experimental paradigms and methodologies for future assessment of human performance, with respect to new technologies (i.e. information displays) used while the human is stationary or moving through the environment. This project is cross-disciplinary involving experts in vision science, biomechanics, computational modelling, education and augmented and virtual reality.

This research fills two key gaps in the literature: understanding the impact of i) AR information presented to one eye, and ii) AR information presentation latency on perceptual, cognitive and physical performance during simple and increasingly complex movement tasks. Information displayed to one eye effectively creates a hole (scotoma) in the visual field. Because the visual fields from each eye overlap, placement of the information in one eye may be monocular or binocular. The placement of this information is important because visual processing differs across the visual field. The latency of visual information in near-to-eye displays impact spatial-temporal perception and proprioceptive responses important to

physical functioning during dynamic tasks. We are conducting studies to investigate how human performance is impacted by changes in latency, and the use of monocular and binocular information. Our approach uses measures of perceptual and cognitive performance, eye and hand movements, and locomotor biomechanics. These data obtained from laboratory and field experiments will provide a picture of how information displays help or hinder an individual's capability to interact with the environment.

Outcomes:
The outcomes of this applied research will provide novel insights into how information displays impact performance during active tasks. This will help inform design principles for development of new information displays. The paradigms developed may be applicable to the testing of next generation information displays, in the field as well as the lab. In this way, an additional outcome is the development of novel assessment methodologies that are sensitive to changes in locomotor biomechanics, sensorimotor, perceptual and cognitive performance.

Next generation colour displays and Laser Eye Protection: optimising both performance and safety

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Background: Technology utilised in air, maritime and land vehicle displays is progressing, resulting in a move from monochrome to coloured displays. Colour is not only preferred by operators[1] but can offer significant advantages, with reports of increased efficiency[2], decreased cognitive load[3] and reduced errors[4]. Laser eye protection (LEP) is commonly required when operating these vehicles. Current LEP technology utilises coloured filters which can alter the colour perceived, increasing the risk of colour confusion or a missed signal. Integrating colour into visual displays will require an understanding of how the display will interact with other aspects of the visual environment including laser eye protection.

Aim: This work aims to characterise the alteration in colour perception produced by current and future laser eye protection in both colour normal and mildly colour vision deficient participants.

Method: Laser eye protection currently in use by rotary wing pilots was identified through a site visit to Army Aviation Centre in Oakey, QLD. Colour vision perception was measured using clinical tests designed to quantify the amount of colour signal required for detection (City University Colour Assessment and Diagnosis (CAD) and Konan ColorDx CCT-HD). These tests were undertaken with and without the laser eye protection in order to separate out the effect of the LEP.

Results: Thus far pilot data from five colour normal and one colour vision deficient participant has been collected. For participants with normal colour vision, a significant decrease in their blue/yellow perception was seen. Our current colour vision deficient participant displayed the most common type of colour vision deficiency-deuteranomaly. With the LEP in place, the colour deficient participant not only demonstrated a reduction in their blue/yellow colour perception similar to that seen in colour normal participants, but displayed improved results for red/green wavelengths.

Conclusions: As colour becomes a commonly used visual cue in the operational environment, understanding the effect of laser eye protection on how the display may be interpreted becomes crucial to avoid colour confusion and missed cues. Laser eye protection currently in use in rotary wing pilots reduces the blue/yellow signal. This should be accounted for when designing colour displays that will be used with LEP.

References:

1. Blundell, J., Scott, S., Harris, D., Huddlestone, J., & Richards, D. (2020). With flying colours: Pilot performance with colour-coded head-up flight symbology. *Displays*, *61* (April 2019), 101932. https://doi.org/10.1016/j.displa.2019.101932

2. Hwang, A. D., Higgins, E. C., & Pomplun, M. (2007). How chromaticity guides visual search in real-world scenes. *Proceedings of the 29th Annual Meetng of the Cognitive Science Society (CogSci'07)*, 371–378. http://csjarchive.cogsci.rpi.edu/Proceedings/2007/docs/p371.pdf

3. Dudfield, H. J. (1991). *Colour head-up displays: help or hindrance ?* 146–150.

4. Turatto, M., & Galfano, G. (2000). Color, form and luminance capture attention in visual search. *Vision Research*, *40*(13), 1639–1643. https://doi.org/10.1016/S0042-6989(00)00061-4

Using Weapon-Mounted Sensors for Combat Shooting Training

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Background: Training of both basic and combat marksmanship skills is costly, time and administratively intensive, and Defence has expressed a desire to increase the amount of training that can be completed without the use of live fire ranges. MantisX, is an example of a cheap, easy to use, off-the-shelf weapon-mounted system that can identify faults and train fine motor skills in Defence personnel, supplementing traditional training throughout their combat marksmanship lifecycle (Biviano, 2021). Previous assessments of the MantisX model's ability to meet this need found the item lacking in Australian-specific teaching points or a suitable profile able to be used with the in-service EF88 assault rifle. The focus now is on developing specifications for the development of an Australian-specific weapon-mounted system for training combat shooting improvements, using the MantisX as an exemplar item. One of the metrics that the MantisX measures is stability of hold, which has been shown to be instrumental to marksmanship performance in studies unrelated to the MantisX (e.g. Mononen, Konttinen et al. 2007). Where the movement of a weapon occurs in space before in relation to after the shot can give some indication of what errors a shooter is making in their grip on the weapon, if they're anticipating or flinching before the shot and more general stability of hold and degree of barrel movement. What is not known about the MantisX is how the errors are characterised, the validity of the errors, how stability in general is defined or whether its use translates to performance improvements.

Aim: The aim of this abstract is to present the proposed multidisciplinary work packagefor discussion and collaboration opportunities to further the development of an Australianisedweapon-mounted sensor to be used to enhance training and the measurement of combat shooting performance.

Method: It is proposed that a number of studies are conducted: 1) user needs elicitation, 2) validation of the MantisX against biomechanical gold standards in the laboratory, 3) show theMantisX can facilitate performance improvements in both skill acquisition and in retrainingpoor movement patterns, 4) develop stability metrics, 5) develop weapon sensors and machine learning algorithms, and 6) develop an app to be used by shooters and their instructors.

Discussion: The studies described are a mixture of current research, post-graduate studies, and studies that are in the proposal phase. It is anticipated that supporting studies, such as understanding skill acquisition and fade, and comparing to other forms of training (e.g. the WTSS)will value-add to this work package.

Conclusions: This abstract describes the need for and path to realising the construction ofan Australian weapon-mounted training system for use by units without the need for live fire or WTSS facilities, or to train shooters showing maladaptive motor patterns such as flinching or anticipation of the shot release.

References:

Biviano, M. (2021). 11/28 RWAR combat shooting data capture system (DCS) training evaluation.Objective ID BQ24652580

Mononen, K., Konttinen, N., Viitasalo, J., & Era, P. (2007). Relationships between postural balance,rifle stability and shooting accuracy among novice rifle shooters. Scandinavian Journal of Medicine and Science in Sports, 17(2), 180-185.

Investigating the benefits and costs of target detection aids

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Background: When a target is cued, observers detect it faster and more accurately than when it is not cued. This benefit for cued targets may be offset by attentional tunnelling, such that observers becomeso focused on the cues that they neglect other critical information. Yeh, Wickens & Seagull (1999) used a simulated aerial reconnaissance task to show that cueing reduced the detection time offrequently presented targets but reduced the detection accuracy (i.e., increase missed rates) of a rare, but high priority, uncued target that was concurrently presented.

Aim: We investigated the benefits and costs on target detection in a military scenario, in which a dismounted combatant performed overwatch duty with simulated augmented reality visual cues. Specifically, we sought to determine whether an unexpected, high priority target might be missed by participants exposed to informative visual cues, and whether the benefits of cueing (facilitation of performance produced by valid cues) were related to their costs (likelihood of missing the unexpected, high priority target). Moreover, we sought to quantify these costs and benefits in terms ofperformance (target detection), overt attention (eye gaze) and covert attention (steady state visual evoked potentials; SSVEPs).

Method: One hundred and twenty undergraduate students played a custom computer game in which they had to protect four friendly soldiers from potential threats, by clicking on any character in the scene who held a weapon. Thirty four characters moved through the scene in each scenario, including 9 male characters who drew a knife and attacked the friendly soldiers. Participants had 2 s to click on these threats after they drew the knife. Participants were divided into three conditions. In the valid cue condition people were shown a red flickering rectangular cue over each of the 9 threat characters. In the invalid cue condition, the flickering cues were non-informative as to whether the highlighted character was a threat. In a third condition, no cues were shown. On the critical trial, a character carrying a rifle walked across the scene in plain view for 20 seconds. Detection of this unexpected target was the primary dependent variable. Overt attention was continuously measured using a 90Hz eye tracker, and covert attention (SSVEPs) was quantified by measuring the occipital power at the frequency that the cues flickered (15Hz).

Results: Valid cues were beneficial in that they attracted attention, and led to participants responding faster and more accurately to frequent (knife-wielding) threats. There was suggestive evidence at the group level that participants shown a valid cue were more likely to miss the rare (rifle-bearing) threat compared to the other conditions. However, at the individual level there was evidence that those who attended most to the cues (indicated by neural SSVEPs) were slowest to identify the unexpected threat, suggesting a direct cost of cueing on performance.

Conclusions: Cueing targets clearly helped observers visually monitor and respond to those targets. However, the presence of cues in the visual scene may lead to costs in responding to critical, unexpected targets that are not cued, but are nevertheless in plain view.

References:

Yeh, M., Wickens, C.D. & Seagull, F.J. (1999). Target Cueing in Visual Search: The Effectsof Conformality and Display Location on the Allocation of Visual Attention. *Human Factors*, 41(4), 524-542.

Augmenting Ability Collaborative Research Centre (CRC) update

Prof. Siobhan Banks

UniSA

Description:
The reasons for augmenting ability vary. Some people may experience challenges from birth. Some experience loss due to an event or over time. While others may seek to improve an area of their ability for work or play. The rapid emergence of complimentary innovative technologies across diverse sectors such as aged and disability care, defence, agriculture, and manufacturing presents an opportunity to develop solutions that enhance human performance across the domains of mobility, thinking, interactions and spaces.

Prof Siobhan Banks (Director: Behaviour-Body-Brain Research Group, UniSA) will provide an overview the proposed CRC, including themes, governance structures, and opportunities for research and industry partners to get involved.

Defence Research Ethics Review: From Compliance to a User-friendly Quality Assurance Mechanism

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Background: The Human and Animal Research Manual (HUMRESMAN 2.0, [ref A]) is a Defence policy framework that translates the National Code [ref B] and National Statement on the Ethical Conduct in Human Research [ref C] into the Defence context. HUMRESMAN 2.0 requires all Defence Human Research, Quality Assurance and Evaluation (QA&E) activities to undergo ethical review and details the mechanisms for this process.

Aim: This presentation will report on the updates underway to the DSTG Research Ethics Review pipeline. These updates aim to meet the required HUMRESMAN compliance and also transform Research Ethics Review into an attractive Quality Assurance mechanism sought after by all its stakeholders. These stakeholders include research ethics applicants and their Defence sponsors, Low Risk Ethics Panel (LREP) members and their counterparts in other Defence Ethics Review bodies. The updated Research Ethics Review pipeline will deliver resources and support for all users of the LREP, enhance its capacity to manage the additional requirements of the policy and address the current increase in demand for human research ethical reviews. This will ensure the delivery of compliant, timely reviews and ethical governance across DSTG and its research partners.

Method: HUMRESMAN 2.0 mandates the review of QA&E activities (e.g., technology trials). As a result, the audience covered by the policy has expanded to include those undertaking QA&E activities that utilise human participants and their data. Research Integrity (RI) and Research Data Governance (RDG) are also new requirements under HUMRESMAN 2.0. Overlaying RDG over existing data security requirements is not trivial. This has been reflected in the development of the Defence Data Strategy [ref D]. The RI functions are key to promoting responsible conduct of research and responding to potential misconduct. They represent a best-practice standard internationally and have been a mandatory requirement for any National Research Organisation since 01 Jul 19. HUMRESMAN 2.0 has aligned Defence policy with this requirement, but now requires integration with DSTG and LREP.

Results: DSTG LREP is finalising the development of resources to align with current policy and other Defence LREPs. These include the implementation of a streamlined online process for researchers seeking ethical review, the development of researcher educational resources (webpage updates, Standard

Operating Procedures and guidelines, and online educational videos), and the implementation of divisional educational roadshows to disseminate the requirements for ethical review and compliance with Defence policy. Under the new policy, the option of Chief-approved protocols is not available; Chief's endorsement for LREP review has been the recommended option (as distinct from Chief's approval bypassing LREP review). The new policy reinforces this recommendation, treating Chief approvals as departure from the policy that can be used as an exception, provided there is a strong rationale for it.

Conclusions: The current review and re-development of DSTG's Research Ethics Review pipeline is an opportunity driven as much by necessity as by the constructive goal of creating a Research Ethics Review enterprise (fit for DSTG but scalable Defence-wide) seen as an attractive Quality Assurance mechanism that is sought after, rather than tolerated, by all of its stakeholders.

References:

HUMRESMAN 2.0 http://intranet.defence.gov.au/home/documents/data/publications/policy-documents/Interim-HUMRESMAN.pdf

https://www.nhmrc.gov.au/about-us/publications/australian-code-responsible-conduct-research-2018

https://www.nhmrc.gov.au/about-us/publications/national-statement-ethical-conduct-human-research-2007-updated-2018

Defence Data Strategy 2021-20, (2021), Australian Department of Defence.

Panel Discussion: Human sciences in the time of COVID

LTCOL Peta Mantel[1], LTCOL Darrin Tyson[1], MAJ Jessica Palling[1], Susannah J. Whitney[1], Troy Visser[2], and Vanessa Bowden[2]

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Background:
Since COVID-19 was declared a pandemic in early 2020, Australians have faced a range of restrictions including lockdowns, prohibitions on interstate travel, and limitations or prohibitions on face to face gatherings. These restrictions have had a significant impact on the Defence human sciences community. For instance, researchers have faced considerable difficulties in conducting laboratory and field experiments, with early reports suggesting that over 60% of researchers have experienced disruption to their work (UK Research & Innovation, 2021). Human sciences researchers have been particularly disrupted, given our work typically requires in-person data collection (Field-Seifer et al., 2020; Myers et al., 2020). However, as a positive, we have seen a rise in the ability to use digital tools to connect nationally and internationally.

In addition, the Australian Defence Force (ADF) has experienced disruption due to COVID-19. The ADF has been required to adjust operations, training, activities, and business in order to follow government health guidelines, while still maintaining operational readiness. Defence has also been supporting the whole-of-government response through the COVID-19 taskforce. This has led to a decrease in the ability of ADF personnel to support studies and experimentation.

Despite these disruptions, there remains a strong need for robust Defence human science to support the ADF in meeting future demands, including responding to the COVID-19 pandemic, and in addressing future strategic challenges (Department of Defence, 2020). This panel brings together a range of stakeholders from Defence and academia to share their experiences on the impact of COVID-19 on their work, and to discuss how the Defence human sciences community can work together to overcome these challenges.

Aim: The panel aims to address questions such as:

- What are the immediate and longer-term impacts of the COVID-19 pandemic on Defence human sciences research?
- How can the human sciences community work together to mitigate these impacts, and continue to deliver outcomes for Defence?
- What new opportunities (if any) for the Defence human sciences communities have emerged from the COVID-19 pandemic, and how can we take advantage of them?

Speakers and topics:

- ADF support to the COVID-19 taskforce - LTCOL Peta Mantel OAM, SO1 Health Intelligence Reform, Army HQ
- The impact of COVID on Army training and operational readiness - LTCOL Darrin Tyson, SO1 Individual Training Operations, and Mr Tom Williamson, HQ Forces Command
- Challenges and opportunities for applied and translational research during COVID-19 - Dr Susannah Whitney, Department of Defence
- Managing research programs during the pandemic - Associate Professor Troy Visser, the University of Western Australia

- The impact of COVID-19 on early career academics - Dr Vanessa Bowden, the University of Western Australia

Outcomes: Through panellist presentations and audience discussion, attendees will share their experiences of working through the COVID-19 pandemic, and insights on strategies to ensure the Defence human sciences community continues to support the Australian Defence Force to meet the challenges of the future operating environment. Insights from the panel will be captured and shared in written format at a later date.

References

Department of Defence (2020) Defence Strategic Update. Canberra, ACT. Commonwealth of Australia.

Feil-Seifer, D., et al. (2020) Where to Next? The Impact of COVID-19 on Human-Robot Interaction Research. *Journal of Human-Robot Interaction* 10 (1) Article 1

Myers, K. R., et al. (2020) Unequal effects of the COVID-19 pandemic on scientists. *Nature Human Behaviour* 4 (9) 2020/09/01 880-883

UK Research and Innovation (2021). Survey findings of the impact of COVID-19 on researchers. Accessed 10 August, 2021, from https://www.ukri.org/news/survey-findings-of-the-impact-of-covid-19-on-researchers/

A biofeedback-enabled, virtual reality, stress management training application for military trainees: From concept development to implementation.

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Background: The Australian Defence Force (ADF) is motivated to expand their existing stress management and resiliency training for serving members, and further enhance the opportunity for individuals to rehearse and apply stress management skills.

Aim: To complement the existing stress management framework, a biofeedback enabled virtual reality training tool was co-designed and co-developed with the ADF (Joint Health Command, Psych Core). The platform is orientated towards ab-initio and initial employment training. Structured in distinct modules, Performance Edge incorporates stress management strategies, that have been extensively validated in other research contexts, for optimising human performance in response to stressful events. Informed by cognitive-behavioural and acceptance and commitment theory, the modules aim to provide immersive scenarios for basic stress management skills development. Performance Edge has been developed to be free-standing, highly configurable to trainer and trainee needs, and immersive while creating a private learning environment for practical training within a classroom setting.

Method: Since the inception of the project in 2018 individual modules are being tested sequentially in civilian and across military populations. User feedback, efficacy and implementation trials have been conducted with an intent to inform the ongoing refinement of content and technology delivery, validate the user acceptance, interaction, and user experience as well as training effects, and identify potential implementation strategies.

Results: To date, 114 ADF trainees across 3 different sites and 50 civilian participants have tested components of Performance Edge in a trial capacity. The outcomes have directly informed hardware updates resulting in a stable, robust, all-in-one VR- biofeedback connection, which has since been seamlessly delivered in classrooms of up to 20 trainees. Our results, so far, show that both the virtual reality and biofeedback technology are suitable for the delivery of stress management training, are

easy to use, setup and navigate, with few technical or implementation issues. The technology actively contributes to the end-user acceptance of the training content and supports skill development. Specifically, the biofeedback functionality, immersion, ability to interact with the environment and the practical training components of Performance Edge have been reported by the users as highly valuable.

Both the grounding and controlled breathing (CB) training modules received positive feedback from trainees and trainers (ADF). After a single training session participants reported high levels of satisfaction, perceived usefulness and suitability, improved skills and knowledge, increased intention to use both grounding and CB and a mindset shift towards the benefits of stress management training in general.

Efficacy testing of the CB module demonstrated both behaviour change and objective improvement in breathing metrics which persisted for at least 1 week (Kluge et al., 2021). Further, pilot testing has indicated that CB training improved recovery times after a real-world training exercise. Grounding training improved the levels of self-reported attention and mindfulness.

Conclusions: Whilst further research on individual components and modules is required and currently under way, the overall training approach, framework, and delivery of Performance Edge appears to provide a promising avenue to improve war fighter performance under stress.

References:

Kluge, M. G., Maltby, S., Walker, N., Bennett, N., Aidman, E., Nalivaiko, E., & Walker, F. R. (2021). Development of a modular stress management platform (Performance Edge VR) and a pilot efficacy trial of a bio-feedback enhanced training module for controlled breathing. *PLOS ONE, 16*(2), e0245068. doi:10.1371/journal.pone.0245068

Fostering Team Resilience via the 'STOP then Resource' Reflection Protocol: A Pilot, Non-Randomised Investigation of Feasibility Within Military Settings

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Background: Interest in developing team resilience (Chapman et al., 2020) is unsurprising, especially within military forces where teams are required to learn and perform in contexts replete with events that challenge collective functioning. While recommendations for developing team resilience exist (e.g., Fletcher & Sarkar, 2016; Sarkar & Page, 2020) they assume specific strategies work well for all teams and are often decontextualised from the nature of adversity. Extending current recommendations within Army (Bond, 2019), and drawing on conceptual work (Gucciardi et al., 2018; Morgeson et al., 2015), we propose an alternative yet complementary approach to foster team resilience by embracing its dynamic nature and focusing on reflections of context-relevant stressor events.

Aim: First, we aimed to translate our theory-based approach into a tangible reflection protocol for use within a military setting. Second, we aimed to explore the feasibility of the protocol and implementation approach via a pilot study with a sample of Army junior leaders.

Method: A mixed-methods, non-randomised study design was employed consisting of two phases.

Phase 1. We conducted a document analysis (Bowen, 2009) of the current doctrine (e.g., guidebooks, white papers) informing reflection processes within military and emergency response organisations, and interviewed key military stakeholders (N = 4) to co-design and implement a protocol suitable to facilitate resilience-focussed team reflections. Interview data was analysed using a content-analysis approach to inform protocol development and implementation.

Phase 2. We adopted a mixed-methods design (Creswell & Clark, 2011) to conduct a process evaluation of the protocol implementation and feasibility. The qualitative component of this phase encompassed content analysis of focus group (n = 4) data gathered from military team leaders (N = 17, M_{age} 25.25±2.57, *Ranks*=10 Corporals, 7 Lance Corporals) to explore perceptions of the protocol. Leader ratings of protocol usability were captured with a modified System Usability Scale (Brooke, 1986) and used descriptively to support interpretation of qualitative findings.

Results:
Phase 1. Document analysis and stakeholder interviews resulted in the development of a five-step worksheet to facilitate team reflections and inform protocol implementation principles (i.e., *who, what, when, where,* and *how*). The acronym 'STOP then Resource' outlined these steps; **S**tressors, **T**iming of stressor events, **O**verview of events, **P**erceived (or actual) impact of stressors, **R**esources (available or required). Descriptions of the five steps were developed to aid protocol understanding.

Phase 2. Qualitative and quantitative feedback from participants provided preliminary support for the protocol, and highlighted areas for future adaption. Briefly, these areas include: targeting junior leaders and newly formed teams; supporting the translation of event experiences into resilience resources at the team level; and integrating reflection processes within existing organisational assessment practices.

Conclusions: We demonstrate the usefulness of a co-design development and implementation framework that engages stakeholders (e.g., military leadership) with subject matter experts (e.g.,

academics, Defence scientists) to develop products that can foster team resilience. Study findings suggest that our reflection protocol offers a feasible and acceptable tool to support military leaders in developing team resilience, yet requires enhancements to maximise uptake and usefulness.

References:

Bond, M. (2019). Commanders' Guide to Resilience: Promoting Unit Resilience (Part 2; pp. 1–45). https://cove.army.gov.au/sites/default/files/06-07/06/180227-Guide-HQ-FORCOMD-Military-Health-and-Psychology-Commanding-Office...-1.pdf

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, *9*(2), 27–40. https://doi.org/10.3316/QRJ0902027

Brooke, J. (1986). SUS: A "quick and dirty" usability scale. In P. W. Jordan, B. Thomas, I. L. Mclelland, & B. Weerdmeester (Eds.), *Usability evaluation in industry* (pp. 189–195). CRC Press.

Chapman, M. T., Lines, R. L. J., Crane, M., Ducker, K. J., Ntoumanis, N., Peeling, P., Parker, S. K., Quested, E., Temby, P., Thøgersen-Ntoumani, C., & Gucciardi, D. F. (2020). Team resilience: A scoping review of conceptual and empirical work. *Work & Stress,* 34, 57–81. https://doi.org/10.1080/02678373.2018.1529064.

Creswell, J. W., & Clark, V. L. P. (2011). Designing and conducting mixed methods research. SAGE Publications.

Fletcher, D., & Sarkar, M. (2016). Mental fortitude training: An evidence-based approach to developing psychological resilience for sustained success. *Journal of Sport Psychology in Action*, *7*(3), 135–157. https://doi.org/10.1080/21520704.2016.1255496

Gucciardi, D. F., Crane, M., Ntoumanis, N., Parker, S. K., Thøgersen-Ntoumani, C., Ducker, K. J., Peeling, P., Chapman, M. T., Quested, E., & Temby, P. (2018). The emergence of team resilience: A multilevel conceptual model of facilitating factors. *Journal of Occupational and Organizational Psychology*, *91*, 729–768. https://doi.org/10.1111/joop.1223

Morgeson, F. P., Mitchell, T. R., & Liu, D. (2015). Event System Theory: An event-oriented approach to the organizational sciences. *Academy of Management Review*, *40*(4), 515–537. https://doi.org/10.5465/amr.2012.0099

Sarkar, M., & Page, A. E. (2020). Developing individual and team resilience in elite sport: Research to practice. *Journal of Sport Psychology in Action*, 1–14.

Trauma history is associated with a 1/f Electroencephalography signature in the MEAOPS combat sample

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Background: Studies have not previously shown a consistent pattern of association between psychological trauma and brain activity measured by electroencephalography (EEG) (Lobo et al, 2015). Traditional EEG analysis considers neural frequency bands (periodic activity) and filters out aperiodic activity (1/f) as noise. Recent evidence suggests that aperiodic activity systematically varies with age, cognitive impairment, and disease status, for example in schizophrenia (Voytek et al. 2015; Peterson et al. 2018; Ouyang et al. 2020).

Aim: In this analysis for the first time, we explore the relationship between historical trauma, PTSD symptoms and aperiodic activity in a military sample.

Method: A subset of Middle East Area of Operation Prospective Study with resting state EEG data (n=142) at baseline was analysed using Fitting oscillation & one over F toolbox to obtain aperiodic measures: 1/f slope and offset. EEG electrode position was included as X (left to right), Y (front to back) and Z (depth) axis coordinates. Exploratory factor analysis (EFA) of historical trauma exposures identified 3 factors: 1(disaster, molestation, witness violence, emotional child abuse), 2(threatened with/without a weapon, experienced violence, witness suicide, physical child abuse), 3(combat, accident, witness kill, experienced assault, found a dead body). Self report symptoms were measured with the PTSD Checklist (PCL). 131 participants were available for linear mixed model analysis with age as a covariate.

Results: Developmental (factor 1) but not mixed (factor 2) or combat (factor 3) trauma was positively associated with PCL scores. 1/f slope with eyes opened (EO) and eyes closed (EC) was negatively associated with factor 1, whereas EO slope was positively associated with factor 3. Significant interactions were observed for electrode axis Z with EO slope, Y and Z for EC slope, EO and EC offset. There was a significant negative interaction between total number of historical traumas and Z, and for timing of trauma (adult vs childhood vs both vs none) with Y,Z for 1/f slope EO and EC.

Conclusions: Reported PTSD symptoms were associated with more prominent developmental rather than past combat trauma. EEG 1/f slope varies across the scalp by type, frequency and timing of trauma exposure. Replication is required but 1/f EEG may be an objective marker of the physiological effects of psychological trauma on the brain.

References:

Lobo, I., Portugal, L.C., Figueira, I., Volchan, E., David, I., Pereira, M.G., de Oliveira, L. (2015) EEG correlates of the severity of posttraumatic stress symptoms: A systematic review of the dimensional PTSD literature. Journal of Affective Disorders, 183, 210-220. https://doi.org/10.1016/j.jad.2015.05.015

Ouyang, G., Hildebrandt, A., Schmitz, F., Herrmann, C.S. (2020) Decomposing alpha and 1/f brain activities reveals their differential associations with cognitive processing speed. *NeuroImage* 205, 116304, https://doi.org/10.1016/j.neuroimage.2019.116304

Peterson, E.J., Rosen, B.Q., Campbell, A.M., Belger, A., Voytek B. (2018) 1/f neural noise is a better predictor of schizophrenia than neural oscillations *bioRxiv* 113449; doi: https://doi.org/10.1101/113449.

Voytek, B., Kramer, M. A., Case, J., Lepage, K. Q., Tempesta, Z. R., Knight, R. T., & Gazzaley, A. (2015). Age-Related Changes in 1/f Neural Electrophysiological Noise. *The Journal of neuroscience* 35(38), 13257–13265. https://doi.org/10.1523/JNEUROSCI.2332-14.2015

The Longitudinal Australian Defence Force (ADF) Study Evaluating Resilience: A summary of key findings and themes from a ten year research program evaluating resilience in early career

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Background: The Department of Defence is committed to contributing to and maintaining the mental wellness of Australian Defence Force (ADF) personnel. As a result, Joint Health Command (JHC) on behalf of the Department of Defence, has conducted the Longitudinal ADF Study Evaluating Resilience (LASER-Resilience) since 2009. This program of research has been conducted in collaboration with Phoenix Australia: Centre for Posttraumatic Mental Health, and is a longitudinal study of the psychological and environmental factors that contribute to or erode the resilience of ADF members.

Aim: The overarching goal of LASER-Resilience was to better understand how military members adjust to the initial stages of their military careers. This project was designed to provide the Australian Defence force (ADF) with valuable information about the situational, organisational and individual factors that both promote and erode psychological resilience in ADF members during their time in training and their first three to four years of service (Crane & Kehoe 2012).

Method: Data was collected over five time points in the early career of military members who enlisted between Nov 2009 and Dec 2012, resulting in an analytic sample of over 5,000 individuals. Nine reports were produced throughout the research program, utilising a range of analytic techniques including Growth Mixture Modelling. These reports addressed a number of research questions of importance to relevant stakeholders at the time of production. This includes the identification of trajectories of mental health disorder and wellbeing, in the context of adjusting to a military career and examining the factors that are associated with these different trajectories. The presentation will focus on the ninth and final report that JHC commissioned Phoenix Australia to produce, the LASER-Resilience Summary Report (Dell et al., 2019). This report summarized the key findings from the previous eight reports and consolidated these findings into eight major themes which emerged consistently across the entire program of research.

Results: The LASER-Resilience research program was able to identify consistent variables that had an impact on wellbeing during potential periods of stress. These variables include social support, leadership, coping styles and sleep.

Conclusions: The majority of the variables identified as important in the LASER-Resilience Summary Report are modifiable. As such, the results from LASER-Resilience have implications for the review or refresh of education, screening and intervention offering.

References:

Crane M & Kehoe EJ (2012). LASER-Resilience Annual Report (R10845868), report prepared for the Australian Government Department of Defence, Australian Centre for Posttraumatic Mental Health, University of Melbourne.

Dell L, Fredrickson J, Sadler N, Terhaag S, O'Donnell M, Crane M, Lewis V & Forbes D (2019). The Longitudinal Australian Defence Force Study Evaluating Resilience (LASER): 2009–19 – a Summary Report of the Research Program, report prepared for the Australian Government Department of Defence, Phoenix Australia, Melbourne.

The Lived Experience of Psychological Contract Formation and Breach in the Australian Defence Force: An Interpretative Phenomenological Approach

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Background: A career as a sailor, soldier, or airman is distinct from many forms of paid work (O'Donnell & Shields, 2002). In countries like Australia, the military is an all-volunteer force, where recruitment relies on staff retention. Recently, Australian military organisations were accused of failing to deliver on *"promises of trade training"* and qualifications, with employees alleging they were *"tricked"* into enlisting (Malone, 2016). This draw links with breach of the psychological contract—the dynamics of the employee-employer relationship (Rousseau 1989). Breaches in psychological contracts are said to occur when an organisation is perceived to have broken the promises it has made (Turnley et al. 2003), or simply, failed to fulfil the terms of its exchange, regardless of whether they were oral, written, explicit or implicit (Montes & Zweig 2009). However, there is a dearth of conceptual investigation regarding the lived experiences of military personnel, particularly with respect to how such contracts form.

Aim: Given concerns around management and promotion of recruitment and retention in military organisations, this study sought to gather first-hand experiences from those who had transitioned into and then out of the armed forces in Australia.

Method: Interviews were conducted using the Critical Decision Method with ex-military personnel (army, navy, air force) and analysed phenomenologically to obtain rich insights into their decision processes, experiences and perceptions (Cane et al. 2010; Curry et al. 2009; Ferroff et al. 2012). A sample of nine subjects was used, in line with recommendations by Creswell (2013) for such an approach. Data gathering led to a focused analysis of textual and structural descriptions, designed to understand common experiences by reflecting on essential themes and what constituted the essence of the experience.

Results: Seven superordinate themes traced the formation and trajectory of the contract of participant. These were: Idealized self; on the edge of your seat futureproofing; information confirmation (through confirmation bias); from second-guessing to sticking to your guns; reality check; military organisation (dis)service; and biting the bullet. Lived experiences pointed to the formulation of "fuzzy" contracts, impressions from defence force recruitment (DFR), specific tipping points around organisational commitment, and large differences between the fidelity of the idealised and actualised self/job. *Simulating* was identified as the essence of contract formation, but also featured across all participant experiences, evoking recent conceptualizations about how the way that people think about work, and the way work is actually done, are not necessarily one and the same (Hollnagel 2016).

Conclusions: Failed expectations are still the major contributor to contract breaches and turnover in the military. The results suggest that the ADF could actively investigate recruits' simulation of their service-as-imagined and equip themselves with the type of information found across the sample—identifying the tangible benefits that shape the foundations of the psychological contract for each individual. This may then enable the ADF to: (1) reshape expectations if they are not realistic; and (2) reshape itself by proposing reforms that aim to deliver the benefits and expectation that first drew the personnel to join.

References:

Cane, S., McCarthy, R., & Halawi, L. (2010). Ready for battle? A phenomenological study of military simulation systems. *Journal of Computer Information Systems, 50*(3), 33-40. Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five traditions* (3rd ed.). London, UK: Sage.

Curry, L. A., Nembhard, I. M., & Bradley, E. H. (2009). Qualitative and mixed methods provide unique contributions to outcomes research. *Circulation, 119*(10), 1442-1452. Ferroff, C. V., Mavin, T. J., Bates, P. R., & Murray, P. S. (2012). A case for social constructionism in aviation safety and human performance research. *Aeronautica, 1*(3). Hollnagel, E. (2016). The nitty-gritty of human factors. In S. Shorrock & C. Wiliams (Eds.), *Human factors and ergonomics in practice: Improving system performance and human well-being in the real world* (pp. 45-64). Boca Raton: FL: CRC Press.

Malone, U. (2016, February 16). Sailors sue Navy saying they were 'tricked' into joining with promises of trades. *ABC News*. Retrieved from Retrieved from http://www.abc.net.au/news/2016-02-15/hundreds-sailors-sue-navy-alleged-false-promises-trade/7170086

Montes, S. D., & Zweig, D. (2009). Do promises matter? An exploration of the role of promises in psychological contract breach. *Journal of applied psychology, 94*(5), 1243-1260. O'Donnell, M., & Shields, J. (2002). Performance management and the psychological contract in the Australian federal public sector. *Journal of Industrial Relations, 44*(3), 435-457. 10.1111/0022185602044003008

Rousseau, D. M. (1989). Psychological and implied contracts in organizations. *Employee responsibilities and rights journal, 2*(2), 121-139. 10.1007/BF01384942

Turnley, W. H., Bolino, M. C., Lester, S. W., & Bloodgood, J. M. (2003). The impact of psychological contract fulfillment on the performance of in-role and organizational citizenship behaviors. *Journal of management, 29*(2), 187-206.

Understanding Navy deployment at sea: Qualitative study of demands, resources, recovery, and resilience during maritime operations.

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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 rangeof 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: Our exploration of the stressors and strains of deployment experiences indicated that the domains of recovery, coping, communication, and help seeking offer the greatest potential when it comes to reducing demands and supporting effective adaptation to the Navy deployment environment. Our qualitative data, also drew attention to the criticality of leadership and supervision for organising and augmenting resources (at the individual and structural levels). The support provided by peers and extended social networks was also seen as a significant contributor to assisting individuals to better cope with work and personal concerns.

Conclusions: This study addresses a current gap in our research understanding of the effects of Navy deployments on the wellbeing and performance of personnel. The intent of this study is to provide rapid and much needed representation of how deployment experience, from the perspective of experienced and diverse experts, impacts upon personnel and identify courses of action to support resilience and recovery within the deployment context.

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.

The Acute Readiness Monitoring Scale (ARMS): Assessing predictive and concurrent validation

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Background: The ability to measure an individual's readiness to perform in an upcoming task can have wide-ranging implications. While tools for the assessment of individual readiness exist in various contexts (e.g., salivary cortisol, heart rate variability), most involve time- and resource-intensive examinations. In response, we developed the Acute Readiness Monitoring Scale (ARMS): a simple multidimensional, self-report tool of perceived readiness. While this tool may have widespread utility in sport and military settings, it remains unknown if the ARMS demonstrates predictive and concurrent validity.

Aim: To investigate whether the ARMS is: 1) responsive to an acute manipulation of readiness using sleep deprivation, 2) relates to biological markers of readiness (cortisol/heart-rate variability), and 3) predicts performance on a cognitive task.

Method: Thirty university students (aged 23 ± 4 years; 18 females) participated. All participants engaged in a 24-hour sleep deprivation protocol. Participants completed the ARMS, biological measures of readiness (salivary cortisol, HRV), and cognitive performance measures (psychomotor vigilance task) before, immediately after, 24-, and 48-hours post sleep deprivation.

Results: All six of the ARMS subscales changed in response to sleep deprivation: scores on each subscale worsened (indicating reductions in perceived readiness) immediately after sleep deprivation, returning to baseline 24/48 hours post. Lower perceived readiness was associated with reduced awakening responses in cortisol and predicted worse cognitive performance (slower reaction time). No relationship was observed between the ARMS and HRV, nor between any biological markers of readiness (cortisol/HRV) and cognitive performance.

Conclusion: These data suggest that the ARMS may hold practical utility in detecting, or screening for, the wide range of deleterious effects caused by sleep deprivation; may constitute a quick, cheap and easily interpreted alternative to biological measures of readiness; and may be used to monitor or mitigate potential underperformance on tasks requiring attention and vigilance.

Decision aids can improve operator resilience by enhancing learning

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Background: It is difficult to calibrate the optimal amount of support a decision aid should provide a human operator. If the aid is highly accurate, the human tends to become reliant and ultimately redundant. If the aid is only partially accurate, the operator will often inappropriately disregard the aid and consequently not benefit from its presence. As part of our Undersea Decision Network project (Huf & Griffiths, 2020), we examined the cognitive components involved in interpreting complex, abstracted sensor data (such as that undertaken by submariners). There appeared to be two distinct goals that each imply different design philosophies: an aid may be designed to provide maximal assistance at the decision time, or it could be designed to maximally support operator learning.

Aim: One experiment tested two decision aids, which were matched in accuracy but differed in visual presentation format. One aid (using highlighting) was designed to optimize speeded performance, while a second aid (using lowlighting) was designed to optimize learning. It was hypothesized that participants' judgments would be better in the presence of the performance-based aid, but that the benefits of the learning-based aid would transfer more readily to a subsequent test in which the aid was removed.

Method: Forty undergraduate students viewed a simulated, simplified narrow-band SONAR display. They were tasked with classifying signals as being generated by either a friend, a foe or neither. After an initial, unsupported training period, they were given further training with one of the two decision aids (a between-subjects manipulation). In a final test block the aids were removed, and unsupported performance was measured to assess transfer. Decision speed, accuracy, eye-gaze and EEG was measured continuously throughout, and subjective measures of workload and trust were taken after each phase.

Results: Behavioural measures of performance indicated superior decision speed and accuracy in the presence of the performance-optimized aid. However, the same metrics indicated superior transfer of the learning-optimized aid to the unsupported test phase, indicating superior learning of the underlying task structure.

Conclusions: By focusing on operator learning rather than performance, it is possible to design decision aids that enhance operators' decisions even when the decision aid itself is withdrawn (or degraded). Such approaches reduce the reliance of human operators on their analytical supports, thereby enhancing the value of the human in the loop even when highly accurate decision aids are available.

References:

Huf, S. & Griffiths, O. (2020) Decision aids that support both learning and performancein complex environments. DPS Research Agreement #10012.

Can communication dynamics be used to predict team cognition in command-and-control contexts?

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Background: Effective communication is vital for teams to interact with each other and coordinate their behaviours. Recent research has established that the dynamics of team communication are associated with changes in team performance.

Aim: This study aimed to investigate how the communication dynamics of novice command-and-control teams were influenced by workload and practice, and to investigate whether machine learning models could be trained to accurately classify team performance based on non-linear measures of team communication.

Method: Ten novice tactical command-and-control teams were required to monitor air traffic through computer-simulated airspace, communicate mission-related information with their team members, and identify and engage hostile aircraft. Each team completed 24 trials consisting of three workload conditions per week over four weeks, with 24 waves of 6-8 aircraft in each trial. Radio communications between team members were recorded and transformed into ordered sequences of nominal data, with each data point indicating if any of the three team members were speaking at discrete one-second time intervals during each trial. The dynamics of each communication sequence were analysed using cross-recurrence quantification analyses (CRQA). Long short-term memory (LSTM) recurrent neural networks were trained to learn the association between the CRQA features derived from team communications and team errors in identifying the hostile aircraft in each wave.

Results: A repeated measures ANOVA found that the effect of task workload on team communication dynamics varied as a function of the number of weeks that the teams had been completing the task together. When task workload was at medium or low levels, communication patterns between team members became more deterministic over time. However, at high workload levels, team communication consisted of lower levels of determinism that remained relatively stable. Team dependent average macro recall for each CRQA feature - for each of the single-channel, feature fusion, and weighted multichannel LSTM networks - were able to correctly classify waves that contained errors with an average recall of 70.8, 76.1, and 80.1 percent, respectively.

Conclusions: The results indicated that communication dynamics were sensitive to task workload and training. Team communication became more regular over time during low and medium workload conditions where team performance errors were relatively infrequent, and less regular in high workload condition where teams had more errors. These results are consistent with previous research showing that relatively greater complexity (less determinism) is symptomatic of more flexible and adaptable teams. They also support a proposed two-phase model of coordination processes in which the adaptation processes of teams are driven by errors. That is, there is less need for planning/realigning behaviours when teams are recording fewer errors, and therefore less complexity in communications. Finally, the results of the neural networks analyses found that features derived from communication dynamics are relatively strong predictors for classifying team performance. In conclusion, the communications-based machine learning models developed for this study can potentially be used to measure and classify team performance in near real-time for team performance monitoring and assessment, and provide an index of team cognition that could be used to modulate human-autonomy interactions.

Understanding how submariner work design relates to performance and workforce sustainability: Preliminary outcomes from a whole-of-workforce survey

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Background: The shift from the current Collins Class Submarines (CCSM) to the future Attack class Submarines (ACSM) will result in many changes to work. For instance, new technologies and systems, altered sleep and respite opportunities, and novel watchkeeping concepts will all change how submariners work and live on board the submarine. To assure enhanced technological capabilities and platform endurance is realised, submariner work design must support optimised human endurance.

The design of work is well established to impact endurance and workforce sustainability outcomes such as fatigue, burnout, engagement, and turnover (e.g., Hu et al., 2011; Andrei et al., 2020). The Job Demands-Resources theory (Bakker & Demerouti, 2014) posits that demanding elements of work, such as high workloads, work/family conflict and unreliable systems can result in burnout, if not balanced with protective elements (i.e., job resources*)*, such as decision-making autonomy and co-worker support. Currently, the unique job demands and resources of submariners are poorly understood. Anecdotal evidence and reviews, such as the 2009 Moffitt Submarine Workforce Sustainability Review, suggest that submariners face significant work/life challenges that increase the risk of turnover. However, there has yet to be a systematic analysis of submariner's demanding and protective job elements and how these relate to endurance and workforce sustainability.

Aim: The research activity is part of a larger research program seeking to understand the drivers of crew endurance and advance a work-life system which optimises crew endurance on the future ACSM. The aim of the current activity is to understand and measure the demanding and protective job elements that are critical in the work design of submariners.

Method: We have developed and administered a survey that measures submariner work design, across all three major settings of their work: at-sea deployments, shore-based activities, and desk duties. Importantly, the operational and deployment-based nature of the role suggests that it is not only work design, but the constraints placed on life when not working (e.g., lifestyle offerings onboard the submarine, and timing/predictability of on shore respite) which may influence crew endurance. As such, 'life design' elements were also measured.

The survey was developed through a semi-systematic review of relevant literatures, including Job Demands-Resources literature, research examining job satisfaction and turnover in Defence Forces, and the Moffitt Submarine Workforce Sustainability Review (2009). The survey was piloted with submariners who assessed survey design and the appropriateness of construct/item selection. The survey was rolled out to the submariner workforce (N =851) in mid-2021. Data collection is expected to be finalised by October 2021.

Results and Implications: This presentation will outline the initial findings of the survey. This includes identifying the job factors (e.g., work-life conflict, task demands, leadership) that have the most significant links with outcomes such as submariner endurance and sustainability. Consideration will be given to how this preliminary data can inform early system design efforts for the ACSM.

References:

Andrei, D. M., Griffin, M. A., Grech, M., & Neal, A. (2020). How demands and resources impact chronic fatigue in the maritime industry. The mediating effect of acute fatigue, sleep quality and recovery. *Safety Science*, *121*(January 2019), 362–372. https://doi.org/10.1016/j.ssci.2019.09.019

Bakker, A. B., & Demerouti, E. (2014). Job demands-resources theory. In P. Y. Chen & C. L. Cooper (Eds.), *Work and wellbeing: Wellbeing: A Complete Reference Guide (Vol. 3, pp. 1–28)*. John Wiley & Sons, Inc. https://doi.org/10.1002/9781118539415.wbwell019

Hu, Q., Schaufeli, W. B., & Taris, T. W. (2011). The job demands–resources model: An analysis of additive and joint effects of demands and resources. *Journal of vocational behavior*, *79*(1), 181-190.

Moffitt, R. A. R. (2008). Navy's response to the submarine workforce sustainability review. https://www.navy.gov.au/sites/default/files/documents/Submarine_Workforce.pdf

A Comparison of Overground and Treadmill Walking During Exoskeleton Assisted Load Carriage

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Background:
Exoskeletons designed for military use aim to reduce injury and improve performance of common warfighter tasks such as load carriage and manual handling (Proud et al., 2020; Young & Ferris, 2016). The need to assess exoskeletons in a controlled laboratory environment is necessary to determine the benefits/disadvantages of the device to inform procurement and R&D decisions. Trials using treadmills instead of overground protocols for gait analysis during load carriage have often been preferred within exoskeleton research (Mooney, Rouse, & Herr, 2014; Panizzolo et al., 2016). However, it remains unknown whether biomechanical and physiological changes when wearing an exoskeleton are comparable between treadmill and overground walking. This is necessary to confirm the benefits/disadvantages of a device can translate from lab trials to field use, and to prevent erroneous conclusions when comparing studies between different research groups.

Aim:
The aim of this project was to compare biomechanical and physiological measures between overground and treadmill loaded (20kg) walking, wearing a passive exoskeleton.
We hypothesise there will be differences between biomechanical and physiological measures during overground and treadmill loaded walking while wearing a passive exoskeleton.

Method:
Six healthy military participants walked on a treadmill and overground at a 0% gradient while carrying a 20kg backpack for 10 minutes at 1.39 m/s[1] (5 km/h[1]). Participants completed each surface condition with and without the exoskeleton. Kinetics (in-shoe forces, three dimensional ground reaction forces, lower limb joint moments), kinematics (lower limb joint angles), gait spatiotemporal parameters, muscle activity, rate of perceived exertion and metabolic cost were measured and calculated. A repeated measures ANOVA and post-hoc two tailed paired sample t-tests were used to compare dependent variables. Significance was accepted at $p< 0.05$.

Results:
Swing time and peak ankle, knee and hip moment during push off were significantly different between overground and treadmill walking during both the control and exoskeleton conditions ($p < 0.05$). When wearing the exoskeleton, peak in shoe forces during push off, peak horizontal ground reaction forces during loading, peak anterior/posterior ground reaction forces during push off and metabolic cost were significantly different between surfaces ($p < 0.05$). Peak knee flexion during loading was significantly different between surfaces in the control condition only ($p < 0.05$).

Conclusions:
In-shoe forces and kinematic measures were mostly transferrable between overground and treadmill loaded walking while wearing a passive exoskeleton. However, the difference in metabolic cost and kinetic measures between surfaces should be considered when assessing advantages/disadvantages of a device. Further, when comparing the results of different exoskeleton evaluations, the selection of laboratory protocol with regards to overground or treadmill walking should be noted.

References:

Mooney, L. M., Rouse, E. J., & Herr, H. M. (2014). Autonomous exoskeleton reduces metabolic cost of human walking during load carriage. Journal of NeuroEngineering and Rehabilitation, 11(1). doi:10.1186/1743-0003-11-80

Panizzolo, F. A., Galiana, I., Asbeck, A. T., Siviy, C., Schmidt, K., Walsh, C. J., & Holt, K. G. (2016). A biologically-inspired multi-joint soft exosuit that can reduce the energy cost of loaded walking. Journal of NeuroEngineering and Rehabilitation, 13(1). doi:10.1186/s12984-016-0150-9

Proud, J. K., Lai, D. T., Mudie, K. L., Carstairs, G. L., Billing, D. C., Garofolini, A., & Begg, R. K. (2020). Exoskeleton Application to Military Manual Handling Tasks. Human factors, 0018720820957467.

Young, A. J., & Ferris, D. P. (2016). State of the art and future directions for lower limb robotic exoskeletons. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 25(2), 171-182.

P3R - A comprehensive analysis of injuries during Army basic military training: Do reporting methods matter?

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Background: Injury during basic military training (BMT) can contribute to attrition and delay graduation (Warfe et al., 2011). Lower extremity musculoskeletal injuries are consistently reported as the most common during BMT, with the majority of injuries diagnosed as overuse (Hauschild et al., 2018; Robinson et al., 2016). The most commonly reported activity in which injury occurs is physical training (Rudzki, 1997; Schram et al., 2019). Yet, only recruits who actively seek 'medical attention' or experience 'time-loss' are typically captured in injury statistics (Hauschild et al., 2018; Pope et al., 2000). Moreover, due to their typical presentation and characteristics, overuse injuries can be difficult to capture (Bahr, 2009). In an attempt to improve injury recording, a definition encompassing all injuries has been recommended (Hauschild et al., 2017), however, methods to effectively capture all injuries must be considered. In sport, self-reported recording methods (Clarsen et al., 2013) and external data collectors present at training sessions (Whalan et al., 2019) have been shown to increase the capture of injuries, and may thus also facilitate injury reporting during BMT.

Aim: To obtain a more comprehensive understanding of injuries sustained during BMT by employing recording methods to capture all injuries.

Method: 646 recruits were assessed over the 12-week Australian Army BMT course. Throughout BMT injury data was recorded via 1) physiotherapy reports following recruit consultation, 2) a member of the research team (third party) present at physical training sessions and 3) recruit daily self-reports. An injury was defined as any physical complaint sustained by a recruit during BMT irrespective of the need for medical attention or time-loss. Physiotherapist and third party reports were linked to an ICD-10-CM code based on body part affected and type of injury (diagnosis). At least 30-days had to pass before a specific ICD-10-CM code (30-day 'gap' rule) could again be counted as a new 'incident injury' (Hauschild et al., 2017). Self-reported injury locations were aligned with body locations from the taxonomy (Hauschild et al., 2017), and the 30-day 'gap' rule applied to specific body locations.

Results: 235 recruits had 21 incident injury recorded by physiotherapists, 365 recruits had 21 incident injury recorded by the third party and 542 recruits reported 21 injury related problem via the self-reported health questionnaire. 621, 687 and 2,964 incident injuries were recorded from 997 physiotherapy reports, 1,937 third party reports and 13,181 self-reported injury-related problems, respectively. The lower extremity was the most commonly injured body region as indicated by all three recording methods, while overuse accounted for 79% and 76% of documented incident injuries from physiotherapist and third party, respectively.

Conclusions: Injury surveillance methods impact injury recording during BMT. The present findings suggest that traditional injury surveillance methods, which rely on medical encounters, underestimate the injury profile during BMT. Considering accurate injury surveillance is fundamental in the sequence of injury prevention, implementing additional injury surveillance methods during BMT may thus improve injury reporting and better inform training modifications and injury prevention programmes.

References:

Bahr, R. (2009). No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. *British Journal of Sports Medicine*, *43*(13), 966-972.

Clarsen, B., Myklebust, G., & Bahr, R. (2013). Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. *British Journal of Sports Medicine*, *47*(8), 495-502.

Hauschild, V., Hauret, K., Richardson, M., Jones, B., & Lee, T. (2017). A taxonomy of injuries for public health monitoring and reporting. *US Army Public Health Centre: Public health information paper (12-01-0717)*.

Hauschild, V. D., Barnes, S., Hauret, K., Lee, T., Forrest, L., & Jones, B. H. (2018). The etiology of injuries in US Army initial entry training. *US Army Medical Department Journal*, *(2-18)*, 22-29.

Pope, R. P., Herbert, R. D., Kirwan, J. D., & Graham, B. J. (2000). A randomized trial of preexercise stretching for prevention of lower-limb injury. *Medicine & Science in Sports & Exercise*, *32*(2), 271.

Robinson, M., Siddall, A., Bilzon, J., Thompson, D., Greeves, J., Izard, R., & Stokes, K. (2016). Low fitness, low body mass and prior injury predict injury risk during military recruit training: a prospective cohort study in the British Army. *BMJ Open Sport & Exercise Medicine*, *2*(1), e000100-000107.

Rudzki, S. J. (1997). Injuries in Australian Army recruits. Part II: Location and cause of injuries seen in recruits. *Military Medicine*, *162*(7), 477-480.

Schram, B., Pope, R., & Orr, R. (2019). Injuries in Australian Army full-time and part-time personnel undertaking basic training. *BMC Musculoskeletal Disorders*, *20*(1), 1-9.

Warfe, P., Jones, D., & Prigg, S. (2011). Developing injury prevention strategies for the Australian Defence Force. *Journal of Military and Veterans Health*, *19*(3), 45-49.

Whalan, M., Lovell, R., McCunn, R., & Sampson, J. A. (2019). The incidence and burden of time loss injury in Australian men's sub-elite football (soccer): a single season prospective cohort study. *Journal of Science and Medicine in Sport*, *22*(1), 42-47.

A longitudinal exploration into the effects of 1RTB military training on aspects of cognition, well-being and diet in Australian Army recruits: Preliminary findings from the HPRnet Microbiome study

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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: 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 was obtained from 82 1RTB recruits completing basic training at Army Recruit Training Centre, Kapooka, New South Wales. Biological samples (saliva, blood, faecal and urine) andsocio-demographic, psychological and physical measures using a range of tests/questionnaires was collected during Week 1, 5/6 and 11/12. Army recruits completed computerised cognitive tasks designed to assess cognitive performance (fluid reasoning, visual processing and attention, short-termand long-term memory, processing speed, executive function, reaction/decision speed and task switching). In addition, recruits completed 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) and/or food dairy). Bloodsamples will be analysed for a range of markers including: metabolites, pro-and anti-inflammatory markers and intestinal permeability. Faecal and saliva samples will undergo 16S rRNA, metagenomics, stress or inflammatory profile analyses. Urine samples will be analysed for a range ofmetabolites (targeted and untargeted metabolomics).

Preliminary Results: Multiple COVID-19 lockdown interruptions have significantly impeded recruitment processes. Of the n=82 recruits, n=40have completed all time points and n=26 have completed two time-point collections. An update on preliminary cognitive performance, self-reported questionnaire and dietary intake findings will be provided.

Key Implications: When complete, the current study will address a major gap in our understanding in the dynamic relationship between environment-warfighter-microbiome interactionsand the translator effects on performance. Additional outcomes include identifying: (1) what does a resilient/preserved cognitive performers' microbiome look like? and (2) those who are at risk, or whodevelop less-desirable brain behaviours (i.e. stress, anxious and depressed) during training, does thisoccur as a result of gut dysbiosis. It is expected that such knowledge will inform the development of novel interventions to support the warfighter in an effort to optimise cognitive performance.

Blood based biomarkers of cognitive and physical performance

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Background: Measurement is a critical first step in the improvement or enhancement of an individual's capabilities. Single measures of speed, accuracy, strength and even cognition can be measured independently. However, human performance remains challenging to measure using existing methodologies which focus on isolated physiological components. This highlights the need to approach the challenge of measuring human performance from a new perspective that encompasses the state of multiple physiological systems in one measurement tool. Our work, and that of others has exploited the peripheral blood as a novel source of biomarkers that are sufficient to diagnose diseases of the central nervous system and predict complex multisystem states.

Aim: Demonstrate that the mind-body connection can be used as a sensor for "human performance". Specifically, here we aimed to test if blood-based biomarkers reflect the current state of substrates of cognition of a trained and physiologically loaded individual.

Method: Funded by Defence Science Technology Group with Next Generation Technology Funds, in collaboration with ARC Centre of Excellence for Nanoscale BioPhotonics, Port Adelaide Football Club and approved by DDVA HREC (173-19), 16 male Australian Rule Footballers were consented and recruited into the trial during the 2020 preseason. Three on ground training sessions were used as study sampling days. On each sampling day the pre-training (20-30 min before), post-training (immediately after) and recovery (1-2h following cool down) study tests were conducted. A venous blood sample was drawn and cognitive testing were performed at each time point on each study day. The cognitive testing measures included the psychovigilance test (PVT), Flanker task and the Inspection time test (IT; only collected on the first study day). Venous blood samples were fractionated and assessed for a stimulated immune response (TLR4–induced and TLR2-induced cytokine response), proteome and glycome analysis on both cell and plasma fractions. Full GPS activity tracker data was also collected. Statistical modelling was performed to identify the factors that allowed for real-time prediction of cognitive performance (within sampling window), and/or predicted near future cognitive performance (between sampling window on study day).

Results: The analysis generated over 2600 markers. By measuring the blood and peripheral immune system of these elite athletes, we identified 60 blood markers that significantly correlated with within-player variability in their current vigilance and/or spatial attention. We also identified markers for their potential use as future performance indicators and novel blood-based markers for injury detection and prediction.

Conclusions: This represents the first blood based glycome and proteome biomarkers that correlate significantly with critical substrates of cognition. These results require replication in an independent study. The mechanistic connection or association between these factors and the altered cognitive performance provide new insights into brain function and opportunities for performance augmentation.

Recruitment into Elite Soldier Units: A Physical Readiness Study

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Background: A key distinguishing feature of effective soldiers in high-performing teams is raised physical prowess. Elite units within the Australian Army administer physical entrance testing (PET) to identify and select candidates to attend an arduous recruitment course (ARC). Passing the PET and ARC is no easy feat. Aspirants must meet challenging PET thresholds for heaves, push ups, loaded running, pack marching and a fully-clothed swim. If selected, they will commence the ARC, where they are faced with a number of rigorous physical tasks over a three-week period.
Force plates are frequently used in human performance optimisation to inform physical readiness and exercise prescription. The countermovement jump (CMJ) and isometric mid-thigh pull (IMTP) are two common tests conducted on force plates. These tests provide insight into absolute and relative power and strength variables.

Aim: This observational study aimed to investigate whether PET, force plate test results and/or performance on select ARC tasks can be utilised to predict overall ARC outcomes.

Method: All potential participants passed the PET and were selected to commence the ARC. Following informed consent, participants conducted CMJ and IMTP tests on dual force plates (VALDForceDecks) prior to the ARC. De-identified individual force plate variables were exported to Excel, along with retrospective PET results, ARC task performance and prospective ARC outcome (e.g. successful or unsuccessful completion). Binary logistic forward conditional multiple regression models were run using the CMJ, IMPT, PET and ARC task performance variables (e.g. loadedrunning and pack march times, physical training rankings, navigation scores etc.) to predict ARC outcome. The cut-offs for being entered in the model was p=0.05 and being removed from the model was p=0.10. IBM SPSS Statistics V24 was used for the analyses.

Results: A number of predictive models based on the PET, force plate tests, and ARC task performance to predict ARC outcome were identified. The best model to identify an unsuccessful ARC outcome, included both PET (pack march only) and force plate (CMJ and IMTP) inputs. This model identified 84.9% of unsuccessful candidates correctly; however, only correctly predicted 44.0%. The best modelto identify completion of the ARC, included only ARC task performance inputs (pack march time and navigation distance), identifying 82.7% of those that were successful but only 59.1% of those that weren't.

Conclusions: Force plate variables of interest may be utilised in a predictive model to 'screen out', but not 'screen in' aspirants for selection after the ARC. Furthermore, force plate testing may inform readiness for prospective ARC aspirants. Results of this study also reinforce the importance ofspecific power and strength training in ARC preparatory programs. This warrants further investigation into the relationship between force plate variables and PET/ARC requirements.

P3R — Physical and Physiological Demands of Basic Military Training

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Background: Basic military training (BMT) requires personnel to perform large amounts of physical activity, with recruits from several countries averaging 13000–17000 steps (~11-14 km) per day (Michael et al., 2021). However, limited data exists regarding how these demands are influenced by the type of training day, as well as the inter-day and inter-person variability. Additionally, there is limited understanding of how daily physical demands influence cardiovascular and perceptual responses to these demands.

Aim: The purpose of this preliminary analysis was to describe the variability in physical activity demands throughout BMT, as well as the cardiovascular and perceptual responses to these demands.

Method: Twenty-nine recruits from the same platoon were observed throughout BMT. Physical activity data (daily step count and time-in-zone distribution) were collected on 65 days (06:30-21:00) from wrist-worn accelerometers (Actigraph GT9X). Heart rate (Polar Team 2) was collected on 27 days and expressed as daily average percentage of heart rate reserve (HRR) and daily time above 60% HRR (T>60%). The NASA task load index (NTLX) was completed at the end of each day, from which the physical demand (NTLX-P) and total demand (NTLX-T) were analysed (scored out of 100). Days were classified as either not including a scheduled physical training (PT) session (NoPT, n=20 days), including a scheduled PT session (PT, n=34 days), or field training during the final two weeks of BMT (FIELD, n=11 days). Data are reported as mean (for each day type) ± standard deviation (across days), as well as the inter-person coefficient of variation (CV). A Pearson's correlation matrix was calculated to investigate relationships among outcomes.

Results: Data for all outcomes are presented in the respective order of NoPT, PT, and FIELD. Daily step counts were 13205±4037, 17280±2582, and 19127±4308 (inter-person CV 16–33%). Accelerometry-derived intensity distributions (percentage time in sedentary/light/moderate/vigorous activity zones) were 28/51/22/0, 21/53/26/0, and 29/46/25/0 (inter-person CV 15–79%). Average daily %HRR was 30±4%, 33±2%, and 34±6% (inter-person CV 8–12%). Daily T>60% was 1±3 min, 25±17 min, and 27±45 min (inter-person CV 49–328%). NTLX-P was 27±20, 53±10, and 50±16, while NTLX-T was 32±15, 45±7, and 40±10 (inter-person CV 41–85%). Accelerometry-derived step counts and moderate physical activity demonstrated weak-to-moderate correlations with heart rate outcomes ($r=0.49–0.65$, $p\leq0.012$), as well as weak correlations with NTLX outcomes ($r=0.25–0.44$, $p\leq0.041$). Heart rate outcomes demonstrated weak-to-moderate correlations with NTLX outcomes ($r=0.48–0.67$, $p\leq0.011$).

Conclusions: These results indicate Australian Army recruits perform a large amount of daily physical activity with most movement classified as low intensity, which is consistent with BMT findings from other countries. The scheduled daily activities (e.g., whether a day includes PT or not) influences the physical

demands and resulting physiological / perceptual responses, meaning careful consideration is required when combining different types of training days into larger (e.g., weekly) summaries. Accelerometry, heart rate, and perceptual measures appear to provide somewhat complementary (rather than overlapping) insight, though it remains to be determined which (if any) measures are associated with training outcomes such as performance, injury, and attrition.

References:

Michael, S.W., Siddall, A.G., O'Leary, T.J., Groeller, H., Sampson, J.A., Blacker, S.D., and J.R. Drain (2021). Monitoring Work and Training Load in Military Settings — What's in the Toolbox? *European Journal of Sport Science,* in press.

Human Intrinsic Capacity Index as a Measure of Performance in Military Science

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Background: The conceptual roots of intrinsic capacity (IC) can be traced to the writings of the philosopher Martha Nussbaum who defined health and wellbeing in terms of people's capacities. In 2015, the World Health Organisation (WHO) introduced the concept of IC to understand human functional capacity and to guide the use of our potential reserve. Intrinsic capacity is defined as a composite of all the physical and mental capacities that an individual can draw upon during their lifetime, based upon the interaction of their genes and their environment. It is measured using five subdomains - cognitive, sensory, locomotor, vitality and psychological. Whether people fully achieve the things that they have reason to value will be determined by their IC, which is inherited and then modified by environmental factors through gene-environment interactions. However, evidence on how genetic and environmental factors come together to influence IC is lacking and no study is yet available. Developing IC index and understanding the biopsychosocial basis of IC is highly relevant for enhancing performance in military settings, thus, military personnel can operate at full capacity.

Method: Using datasets from international biobanks, we will develop IC index score, perform Genome-Wide Association Analyses (GWAS), genes to environment (G x E) interaction analyses and functional interpretations of the findings followed by the development of a biological model for intrinsic capacity (IC). Genetic and phenotypic datasets obtained from the UK Biobank (N=500,000) and the Netherlands LifeLines cohort (N=167,000) will be utilised as discovery and replication samples, respectively. As a first step, we compute an index score for IC. The IC index will be constructed as a latent measure of IC using five key subdomains cognitive, sensory, locomotor, vitality, and psychological domains. In a second step, we estimate heritability of IC using SNP-based mixed-model analysis method implemented in Genome-wide Complex Phenotype Analysis (GCTA) software. In a third step, we identify genetic markers and biological pathways for IC. In a fourth step, we investigate gene-environment (G x E) interactions. The results obtained from using the UK Biobank data will be replicated in the LifeLines cohort.

Results: First, environmental factors highly relevant to the variability of IC, as evidenced by previous studies (age, gender, exercise/activity, sleep, smoking, alcohol use, diet and sociodemographic status) will be selected. Then by using previously published methods and freely available software packages (PLATO) and the SIMreg R package, I will perform a genome-wide G x E and SNP x E interactions analysis.

Discussion: This project will develop an index score for a relatively new concept of 'intrinsic capacity (IC)' and will answer fundamental questions about how genetics and the interaction between genetic and environmental factors regulate an individual's IC, with the findings from this work

providing enormous scope and wide interest to researchers in multiple disciplines including applications to defence-relevant high-performance environment. Knowledge gained from this project can be used as a basis for developing personalised IC-based performance interventions, to promote a full realisation of a military personnel's intrinsic capacities.

The Effect of Biological Sex on Lower-Limb Coordination Variability During Load Carriage

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Background: Load carriage related injuries directly impact military personnel's availability for service, with 34% of soldiers having sustained one across their career (Orr et al., 2017). Female soldiers are more likely to sustain either a serious time-loss injury (~2.4 fold increase), stress fractures (~4 fold increase) or any other injury (~2 fold increase) than male soldiers (Bell et al., 2000; Knapik et al., 2012; Orr & Pope, 2016). Lower-limb coordination variability (CV) has been equivocally linked to injury, with both higher and lower CV being observed in injured individuals compared with healthy controls (Davis et al., 2019). While biological sex has been reported to affect lower-limb CV during non-loaded locomotion tasks (Boyer et al., 2016; Pollard et al., 2005), its effect on lower-limb CV during load carriage tasks remains unknown.

Aim: To investigate the effect of biological sex on lower-limb CV during load carriage.

Method: Twenty-six participants (13 female, 13 male) with no prior heavy load carriage experience completed a 10-minute treadmill-based walking task wearing body-borne external load (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 segment kinematics of the thigh, shank, and foot. The standard deviations of continuous relative phase quantified lower-limb CV across 19 strides for Thigh-Shank, Shank-Foot and Thigh-Foot couplings. The effect of biological sex on CV was assessed using statistical parametric mapping paired *t* tests (Pataky et al., 2013). Cohens d_z effect sizes were also calculated for each percent of the gait cycle.

Results: There were no significant (p>0.05) biological sex differences in CV any examined coupling. In the Thigh-Shank coupling, lower-limb CV was similar across the gait cycle, although females were 14% higher during late stance (d_z=-0.16). For the Shank-Foot coupling, the female's CV was ~24% higher during early stance (d_z=-0.41). For the Thigh-Foot coupling, the male's CV was ~8% higher during early stance (d_z=0.13) and the females CV ~11% higher during the swing phase (d_z=-0.13).

Conclusions: There were no significant differences in lower-limb CV between sexes for any coupling examined. This contrasts previous research that has observed females with greater and lower CV during overground running and cutting manoeuvres, respectively (Boyer et al., 2016; Pollard et al., 2005). Such differences may reflect the differing task complexities employed by the separate studies, suggesting that lower-limb CV may be task dependent. Additionally, the current cohort were load carriage naïve which limits the application of the findings to military personnel. It is possible that the relative inexperience of both sexes resulted in the same adaptive behaviour to the introduction of load as a perturbation during walking. Rather, it is possible that in experienced load carriage populations such as military personnel, a different response between sexes might exist. Although the cohorts were load carriage naïve, the present findings suggest that load carriage training does not seem to elicit a sex-dependent CV response. Future research could explore whether there are any biological sex-based differences in prospective CV response with load carriage exposure.

References:

Bell, N. S., Mangione, T. W., Hemenway, D., Amoroso, P. J., & Jones, B. H. (2000). High injury rates among female army trainees: A function of gender? *American Journal of Preventive Medicine*, *18*(3 SUPPL.), 141–146. https://doi.org/10.1016/S0749-3797(99)00173-7

Boyer, K. A., Freedman Silvernail, J., & Joseph, H. (2016). Age and sex influences on running mechanics and coordination variability. *Journal of Sports Sciences*, *35*(22), 2225–2231. https://doi.org/10.1080/02640414.2016.1265139

Davis, K., Williams, J. L., Sanford, B. A., & Zucker-Levin, A. (2019). Assessing lower extremity coordination and coordination variability in individuals with anterior cruciate ligament reconstruction during walking. *Gait and Posture*, *67*(2), 154–159. https://doi.org/10.1016/j.gaitpost.2018.10.010

Knapik, J., Reynolds, K., Santee, W. R., & Friedl, K. E. (2012). *Load Carriage in Military Operations: A review of historical, physiological, biomechanical and medical aspects*. Fort Detrick, Maryland: Office of The Surgeon General.

Orr, R. M., Coyle, J., Johnston, V., & Pope, R. (2017). Self-reported load carriage injuries of military soldiers. *International Journal of Injury Control and Safety Promotion*, *24*(2), 189–197. https://doi.org/10.1080/17457300.2015.1132731

Orr, R. M., & Pope, R. (2016). Gender differences in load carriage injuries of Australian army soldiers. *BMC Musculoskeletal Disorders*, *17*(1), 1–8. https://doi.org/10.1186/s12891-016-1340- 0

Pataky, T. C., Robinson, M. A., & Vanrenterghem, J. (2013). Vector field statistical analysis of kinematic and force trajectories. *Journal of Biomechanics*, *46*(14), 2394–2401. https://doi.org/10.1016/j.jbiomech.2013.07.031

Pollard, C. D., Heiderscheit, B. C., Van Emmerik, R. E. A., & Hamill, J. (2005). Gender differences in lower extremity coupling variability during an unanticipated cutting maneuver. *Journal of Applied Biomechanics*, *21*(2), 143–152. https://doi.org/10.1123/jab.21.2.143

Author, G.W. & Writer, R.J. (1995). Science of the flying disc. *Journal of Human Engineering*, 111, 155-173.

Wordsmith, D.J. & Scribbler, R.A. (1991). *Occupational Biomechanics*. New York: Elsevier.

The Effect of Weapon Handling on Stride Time Variability

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Background: Gait biomechanics when carrying body-borne loads are a focus of military study to optimise performance and minimise/identify injury risk (Majumdar, Pal, & Majumdar, 2010). However, there is limited literature on the impact of weapon handling (Attwells, Birrell, Hooper, & Mansfield, 2006; Walsh & Low, 2021), which increases ground reaction force (Birrell & Haslam, 2008) and decreases pelvis and trunk coordination variability (Seay, Hasselquist, & Bensel, 2011). Stride time variability has been shown to differentiate between healthy locomotor function and those at risk of falls (Hausdorff, Rios, & Edelberg, 2001), motor diseases (Zanardi et al., 2021) or previous history of injury (Meardon, Hamill, & Derrick, 2011). The effect of weapon handling on stride time variability is currently unknown.

Aim: To investigate the effect of weapon handling on stride time variability.

Method: Fifteen Australian Army soldiers (5 f / 10 m, height 172 ± 23 cm, mass 86 ± 29 kg, age 26 ± 6 y) completed two 12-min walking trials on a force instrumented treadmill at 5.5 km/h. Trials were performed either with (W) or without (WO) a replica f88 Austeyr (3.2 kg; held in two hands across the body) whilst carrying 23 kg of load (including weapon mass) evenly distributed by a vest.

Heel contacts were identified using peak detection of the anteroposterior centre of pressure displacement obtained from the embedded force plates. Stride time was calculated as the time interval between successive heel contacts of the right foot and the mean stride time calculated for 500 strides. The magnitude of stride time variability was calculated as the standard deviation of stride time and the coefficient of variation of stride time. Detrended fluctuation analysis (DFA) alpha was used to measure the time-dependant structure of stride time variability. Paired *t* tests were performed to investigate the effect of weapon handling on each variable with significance accepted at $p < 0.05$. Cohen's d_z effect sizes were calculated (Cohen, 1988).

Results: No statistically significant differences were found between carrying and not carrying a weapon. The DFA alpha (W: 0.81 ± 0.12, WO: 0.79 ± 0.13, $p = 0.600$, $dz = -0.14$), stride time mean (W: 1.05 ± 0.05 s, WO: 1.05 ± 0.05 s, $p = 0.250$ $d_z = 0.31$), standard deviation (W: 0.014 ± 0.003 s, WO: 0.15 ± 0.003 s, $p = 0.622$, $d_z = 0.13$) and coefficient of variation (W: 1.38 ± 0.28 %, WO: 1.41 ± 0.29 %, $p = 0.641$, $d_z = 0.12$) were similar between conditions.

Conclusions: These results demonstrated that stride time variability remained similar with and without weapon handling when carrying body-born loads. The comparable structure and magnitude of stride time variability may indicate that participants' locomotor systems were able to adapt to the task constraint of carrying a weapon. It could also be interpreted that the weapon was not enough of a perturbation to affect stride time variability. Previous research has found that cognitively demanding tasks affect stride time variability (Springer et al., 2006). Weapon handling may not compromise gait adaptability, which could support increased weapon handling during training, aiding soldiers'

progression and experience. Future studies should explore how other real-world constraints such as speed, load, cognitive demand, and terrain interact with weapon handling to see if variability changes.

References:

Attwells, R., Birrell, S., Hooper, R., & Mansfield, N. (2006). Influence of carrying heavy loads on soldiers' posture, movements and gait. *Ergonomics, 49*, 1527-1537. doi:10.1080/00140130600757237

Birrell, S., & Haslam, R. (2008). The influence of rifle carriage on the kinetics of human gait. *Ergonomics, 51*, 816-826. doi:10.1080/00140130701811859

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, N.J.: L. Erlbaum Associates.

Hausdorff, J. M., Rios, D. A., & Edelberg, H. K. (2001). Gait variability and fall risk in community-living older adults: A 1-year prospective study. *Archives of Physical Medicine and Rehabilitation, 82*(8), 1050-1056. doi:10.1053/apmr.2001.24893 PMID - 11494184

Majumdar, D., Pal, M. S., & Majumdar, D. (2010). Effects of military load carriage on kinematics of gait. *Ergonomics, 53*(6), 782-791. doi:10.1080/00140131003672015

Meardon, S. A., Hamill, J., & Derrick, T. R. (2011). Running injury and stride time variability over a prolonged run. *Gait and Posture, 33*, 36-40. doi:10.1016/j.gaitpost.2010.09.020 PMID - 21036046

Seay, J. F., Hasselquist, L., & Bensel, C. K. (2011). Carrying a rifle with both hands affects upper body transverse plane kinematics and pelvis–trunk coordination. *Ergonomics, 54*(2), 187-196. doi:10.1080/00140139.2010.538726 PMID - 21294016

Springer, S., Giladi, N., Peretz, C., Yogev, G., Simon, E. S., & Hausdorff, J. M. (2006). Dual-tasking effects on gait variability: The role of aging, falls, and executive function. *Movement Disorders, 21*(7), 950-957. doi:https://doi.org/10.1002/mds.20848

Walsh, G. S., & Low, D. C. (2021). Military load carriage effects on the gait of military personnel: A systematic review. *Applied Ergonomics, 93*, 103376. doi:https://doi.org/10.1016/j.apergo.2021.103376

Zanardi, A. P. J., da Silva, E. S., Costa, R. R., Passos-Monteiro, E., dos Santos, I. O., Kruel, L. F. M., & Peyré-Tartaruga, L. A. (2021). Gait parameters of Parkinson's disease compared with healthy controls: a systematic review and meta-analysis. *Scientific Reports, 11*(1), 752. doi:10.1038/s41598-020-80768-2

Decision strategies: causal investigations of the trade-off between decision speed and accuracy in the frontal cortex

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Background: The ability to strategically adapt how we make decisions is important in a range of everyday settings. For example, if you're running late you may choose to drive relatively fast, but if you turn a corner and find thick fog you may (and should) re-evaluate your chosen speed and slow down. One key decision strategy is the speed accuracy trade-off (SAT; the faster people respond the more likely they are to make an error), and it is arguably the most robust finding in cognitive psychology. Neuroimaging has implicated two frontal regions as neural substrates of the SAT: the posterior lateral prefrontal cortex and the preSMA (part of the superior medial frontal cortex; SMFC). However, there is no causal evidence for these regions involvement in the SAT, nor is it clear what role each plays in the underlying processes.

Aim: This work aims to causally elucidate the role of the left prefrontal cortex and SMFC in decision strategies.

Method: Across two double-blind, pre-registered studies, we applied cathodal transcranial direct current stimulation (tDCS) to prefrontal and SMFC. The SAT was measured using a dot-motion task. In Study 1 (41 participants), we varied participants explicit response strategy (focus on accuracy, speed, or both). In Study 2 (42 participants) we employed an incidental manipulation of decision strategy via varying variability in task signal.

Results: In Study 1, both target regions modulated decision strategies but in opposing directions. Specifically, stimulation to the left prefrontal cortex made participants more cautious in their decisions, whereas stimulation to the SMFC led to reduced caution in decisions. These effects were most pronounced when participants were instructed to focus on accuracy over speed. In Study 2, stimulating the two regions again led to dissociable effects on decision strategies, although these did not interact with our implicit manipulation of decisions.

Conclusions: Overall, the findings indicate that both the SMFC and the prefrontal cortex are causally involved in decision strategies, but play distinct roles. This work furthers our understanding of the neural basis of the SAT and presents an opportunity for future research to optimise decision performance.

Predicting performance on a simulated submarine control room task from discrete cognitive abilities and resting-state EEG

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Introduction: Optimal personnel selection is essential for successful operational outcomes. Brain activity while at rest (measured by electroencephalography; EEG) may offer a window into an individual's performance capabilities across a variety of settings. Previous neuroscientific research has demonstrated how specific characteristics of "resting-state" neural metrics (individual alpha frequency; IAF and the slope/intercept of aperiodic 1/*f* activity) are associated with superior cognitive functioning and performance (i.e., faster processing speed, higher IQ and greater memory capacity). However, effects of such resting-state neural metrics on higher-order cognition have not been studied using complex, semi-naturalistic tasks. The current study aimed to investigate how individual neural metrics – alongside traditional cognitive test scores – predict performance in dynamic settings and on realistic military tasks.

Methods: Thirty-nine adults (15 male; mean age = 24.34, range: 18 – 40) provided two minutes of resting-state EEG recording for the calculation of individual neural metrics. Participants then completed a series of traditional cognitive tests to measure discrete cognitive abilities (i.e., working memory, visual statistical learning and spatial imagery) and engaged in a modified version of the Control-Room-Use-Simulation Environment (CRUSE) wherein participants were required to act as a submarine's target motion analyst, necessitating the rapid integration of multiple sources of dynamically changing information. In the CRUSE, participants first completed a 40-minute familiarisation and then a 40-minute performance testing session. Performance on CRUSE was quantified using tactical picture error (TPE). TPE encodes information regarding the difference between the solutions plotted for all contacts and the simulation's 'truth' of the surrounding environment, with a lower TPE reflecting better performance.

Results: We used mixed effects modelling for statistical analysis of non-linear fluctuations in CRUSE performance over time. Our results demonstrate that higher spatial imagery ability was related to superior performance (a decrease in TPE) across both test and practice sessions ($\chi 2(4) = 28.05$, $p < .001$). For individual neural metrics, higher IAF was related to more rapid adjustment to CRUSE task demands when compared to those with lower IAF ($\chi 2(4) = 35.75$, $p < .001$). For aperiodic measures, we observed that a flatter $1/f$ slope (associated with greater neural complexity) was related to better performance in portions of the practice session, but this effect did not persist into the test session. We also observed a relationship between the $1/f$ intercept (an index of overall neural firing rate) and performance in both CRUSE sessions, whereby a higher intercept was related to greater performance in the test session.

Conclusion: Our results provide promising evidence that resting-state neural metrics can complement and extend traditional cognitive measures to predict individual performance in complex operational environments. These neural metrics were most strongly predictive of performance in the practice session and early portions of the test session, thus indicating that they reflect how quickly individuals can adapt to the novel demands of the CRUSE task, and by inference, to any complex decision-making task. We thus suggest that measures of neural activity at rest could be used to predict an individual's aptitude for agile decision making, with potential implications for personnel selection in defence settings.

Random Forest for Event Classification of Eye Movements: Towards Effective Cognitive Workload Estimation

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Background: Classifying eye tracking data into discrete oculomotor events (eye fixation, saccades, and post-saccadic oscillations) is crucial for eye movement research. In general, event detection algorithms can be summarised into four categories, namely velocity-based, dispersion-based, probabilistic-based, and machine learning (ML) based. The major drawbacks for the first three (non-ML) approaches is that they require users to manually select thresholds based on hand-crafted signal features for event classifications. These thresholds can be highly subjective to the perspective of the decision maker and the velocities of eye movements can also vary for different tasks, thus the threshold selection process is nontrivial. Such discrepancies can lead to biases and wrong interpretations in research activities based on them. Therefore, an autonomous and unbiased approach for classifying oculomotor events is needed.

Aim: ML have proven to be highly effective in classification tasks. Most research in eye movement classification, however, have been conducted based on time-consuming manual event detection or by non-ML algorithms based on a set of rules with parameters chosen manually according to some given performance measures. In this work, we aim to evaluate the performance of a random forest classifier by comparing it with other existing ML approaches and assess its applicability for oculomotor event classification applications.

Method: In this work, we implemented and evaluated a random forest classifier for robust event detection using features including raw gaze X and Y coordinates, and pupil size of time series. We classify eye movements into six events, namely, fixation, saccade, post-saccadic oscillation, smooth pursuit, blink, and noise. For benchmarking, we used the dataset published by Lund University that contains 350,631 samples (Larsson et al. 2013). It has been manually annotated into the six eye movement events, which aligns with our objective. We used 80% of the samples for training and the remaining 20% for testing. The model is implemented in Keras using 30 estimators and an entropy function for probability distribution. Our proposed method is fully automated, end-to-end generalized, has no dependency on any threshold, and requires no pre-processing on raw data or post-processing steps.

Results: We have performed a series of analyses on ML-based event classification. Our random forest classifier has outperformed other existing ML approaches under test with an overall accuracy of 97%. Others (Hoppe et al., 2016, Startsev et al., 2019, Zemblys et al., 2019, and Marie et al, 2019) have shown accuracies of 71%, 83%, 93% and 94% respectively, and they can only classify eye movement data into three events while the proposed method can work on six categories.

Conclusions: Eye movement event classification is essential for eye tracking applications in education, training, marketing, psychology, and medical image interpretation. It can also be used to identify fatigue, stress, and cognitive workload. To provide a universal approach irrespective of sampling rate or task dependency for cognitive workload classification using ML approaches, data augmentation will be used in our future work to improve the performance of the proposed solution by avoiding overfitting. Next, we will use unsupervised learning for cognitive workload detection.

References:

Larsson, L. (2016). Event detection in eye-tracking data for use in applications with dynamic stimuli (*Doctoral dissertation, Lund University*).

Hoppe, S., & Bulling, A. (2016). End-to-end eye movement detection using convolutional neural networks. *arXiv* preprint arXiv:1609.02452.

Startsev, M., Agtzidis, I., & Dorr, M. (2019). 1D CNN with BLSTM for automated classification of fixations, saccades, and smooth pursuits. Behavior *Research Methods*, 51(2), 556-572.

Zemblys, R., Niehorster, D. C., & Holmqvist, K. (2019). gazeNet*: End-to-end eye-movement event detection with deep neural networks*. *Behavior research methods*, 51(2), 840-864.

Bellet, M. E., Bellet, J., Nienborg, H., Hafed, Z. M., & Berens, P. (2019). Human-level saccade detection performance using deep neural networks. *Journal of neurophysiology*, *121*(2), 646-661.

Case Study: Ethical AI in Defence and Allied IMPACT

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Abstract:

The use of artificial intelligence (AI) in a defence context poses significant ethical questions and risks. Defence will need to address these as AI systems are developed and deployed in order to maintain the reputation of the ADF; uphold Australia's domestic and international legal obligations; and support the development of an international AI regime based on liberal democratic values.

This report, 'Case Study: Ethical AI in Defence and Allied IMPACT' uses 'A Method for Ethical AI in Defence' [Devitt, K., Gan, M., Scholz, J., Bolia, R.; DSTG; 2020] to explore the ethical risks in an AI-enabled decision support tool, Allied IMPACT (AIM), which uses autonomous functions to assist human operators to manage multiple unmanned vehicles simultaneously.

The analysis of AIM using A Method for Ethical AI in Defence generated key findings for three stakeholder group: whole-of-Defence; AIM system developers, and those seeking to use or iterate 'A Method for Ethical AI in Defence'.

For Defence, the report identifies critical policy gaps and recommends action on: an accountability framework for decisions made by and with AI; education and training of operators, Command and systems developers; and managing the data underpinning many AI applications, including its collection, transformation, storage and use. Without action, these gaps leave Defence vulnerable to significant reputational and operational damage.

Additional key findings for AIM developers relate to the topics of effectiveness; integration; authority pathway; confidence; and resilience.

Getting Team Members on the Same Page by Enhancing Shared Mental Models: A Systematic Review and Meta-Analysis of Controlled Trials

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Background: Teams are the foundation of Defence's operational capability. The ADF has identified as a priority area for research the need to enhance the resilience of teams to operate in challenging environments. Grounded within a broader program of research on team resilience, we identified shared mental models (SMM) as one key element for team resilience emergence (Gucciardi et al, 2018). Essentially, when team members 'are on the same page' regarding key taskwork and teamwork elements they are best positioned to anticipate and react effectively to situational demands as well as the needs, duties, and actions of their team members (Cannon-Bowers & Salas, 2001). Narrative reviews (Mohammed et al., 2010) and statistical syntheses of empirical data (DeChurch & Mesmer-Magnus, 2010a, 2010b) support the salience of SMM as a determinant of a range of collective states, processes, and outcomes. Yet our knowledge of factors that can enhance SMM remains underdeveloped and therefore insufficient for theory development and practice, primarily because the evidence is fragmented across diverse scientific disciplines and occupational contexts. We focus on team development interventions (TDIs), which refer to "actions taken to alter the performance trajectories of organisational teams" (Shuffler et al., 2018, p. 689).

Aim: We aimed to assess the evidence for TDIs as a means by which to enhance SMM, with the view to guide decision-making about the best ways to prepare individuals and teams cognitively for the demands of operational performance.

Method: We conducted a systematic review and meta-analysis of randomised controlled trials to identify eligible studies and statistically synthesise evidence from 36 lab or field experiments (131 effect sizes, $N_{participants}$ = 6,209, N_{teams} = 1,912) testing the effectiveness of TDIs for enhancing SMM.

Results: We found a positive and significant medium-to-large overall effect of TDIs on SMM (g = .61, 95% CI = .41, .82); sensitivity and meta-bias analyses generally supported the robustness of this overall effect. Moderator analyses indicated stronger effects observed when outcomes were researcher- assessed (versus self-report or objective). Nevertheless, our assessment indicated low certainty in the quality of the evidence and 'noisiness' in the overall estimate (i.e., prediction interval of -0.66 and 1.89). Our narrative synthesis of effective interventions partially supported the importance of actively engaging members with essential knowledge, providing opportunities to communicate that information with each other for enhancement of SMM, and augmenting the work environment to optimise collaborative interactions among members. Notably, none of these experiments were conducted with military samples.

Conclusions: The findings from this meta-analysis provide a cautiously optimistic view of the potential of TDIs as a means by which to enhance SMM among teams. There remains several challenges (e.g., diversity in the operationalisation of SMM and types of intervention) and opportunities (e.g., enhanced

transparency in reporting, development of standardised protocols) that require attention in future scholarly work if the concept of SMM is to fulfil its potential in science and practice. Understanding the shared knowledge requirements of military team-based tasks will be important for the development and application of reliable SMM measures and protocols in military settings.

References:

Cannon-Bowers, J. A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In J. N. Castellan Jr. (Ed.), *Individual and group decision making* (pp. 221-246). Hillsdale, NJ: Lawrence Erlbaum

DeChurch, L. A., & Mesmer-Magnus, J. R. (2010a). The cognitive underpinnings of team effectiveness: A meta-analysis. *Journal of Applied Psychology, 95*, 32–53. doi: 10.1037/a0017328

DeChurch, L. A., & Mesmer-Magnus, J. R. (2010b). Measuring shared team mental models: A meta-analysis. *Group Dynamics: Theory, Research, and Practice*, *14*, 1-14. doi: 10.1037/a0017455

Gucciardi, D. F., Crane, M., Ntoumanis, N., Parker, S. K., Thøgersen-Ntoumani, C., Ducker, K. J., ... & Temby, P. (2018). The emergence of team resilience: A multilevel conceptual model of facilitating factors. *Journal of Occupational and Organizational Psychology*, *91*(4), 729-768. doi:10.1111/joop.12237

Mohammed, S., Ferzandi, L., & Hamilton, K. (2010). Metaphor no more: A 15-year review of the team mental model construct. *Journal of Management*, *36*, 876-910. doi: 10.1177/0149206309356804

Shuffler, M. L., Diazgranados, D., Maynard, M. T., & Salas, E. (2018). Developing, sustaining, and maximizing team effectiveness: An integrative, dynamic perspective of team development interventions. *Academy of Management Annals*, *12*, 688-724. doi: 10.5465/annals.2016.0045

The Impact of Leadership Behaviours on Team Trust, Team Voice and Decision Making in the Extreme Action Teams

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Abstract:
Background: Extreme Action Teams (EAT) operate in unpredictable, low-information, and volatile environments. EATs (including under-sea, space, and isolated exploration missions) have stable command-control hierarchical structures and technical role differentiation among members. Leadership in such teams pose unique challenges wherein the leader is responsible for diagnosing the situation and making effective decisions while simultaneously relying on information captured and relayed by subordinate team members with technical expertise tied to specialised roles. Thus, the leader's behaviours become a critical predictor of how team trust and voice develop and whether they support or interfere with decision-making performance.

Aim: This work aimed to build a rich qualitative understanding of the decision-making context's critical characteristics in extreme action teams. We focused on EATs in the Maritime context. The purpose was to identify the role of different leader behaviours, particularly empowering versus directive leadership, on how teams build psychological safety to voice, trust among themselves and high effectiveness in decision making.

Method: This study adopted a "Grounded Theory Method (GTM)" that allows for the "discovery of theory from data. We interviewed retired former leaders from the Maritime division of the ADF. They shared their decision-making experiences in EATs and what they believed enabled and interfered with team performance. The interviews allowed for iterative refinement of themes through the discovery process. NViVO was used to code for the first order and second-order themes related to leadership, voice, trust and decision making performance.

Results: We provide a brief overview of the key themes that emerged from the data; the details for each theme would be discussed in the oral presentation. The most critical leadership behaviours to enable trust-building and facilitate team member voice included: 1) Engaging in both hierarchy-based protocols for information flow as well as purposefully breaking the chain to seek information from junior members; 2) Allowing space for members to make mistakes (trust granting) during less critical missions; 3) Displaying consistency in behaviour particularly maintaining emotional calm and not playing favourites; 4) Communicating openly to the whole team to foster shared situational awareness and asking questions of the team as a whole and not individuals; 5) Facilitating downtime interactions amongst team members and having casual conversations about life outside the job to build connection and 6) Showing humility by acknowledging one's fatigue and seeking inputs from others.

Conclusions: Team trust and team voice came out as critical drivers of effective team decision-making. The leadership framework from this data allowed us to develop a comprehensive taxonomy of leader behaviours that enable trust and voice in teams. This leader behaviour framework can be the critical basis for designing leadership training and protocols for after-action reviews and other team performance management systems for EATs. This work was undertaken under DSTG RN-UDS Agreement 10011.

Team Dynamics for Enhancing Decision-Making

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Background: Within high-tempo military environments, the quality of decisions made is critical for the success of operations. Literature within psychological and management fields of research indicate that decision quality can be increased through the dissemination of unique opinions—referred to as dissent—as it enables greater informational inputs to be integrated into complex problems. Our conceptual model integrates an expanse of social and organisational psychological literature and superordinates various constructs into three variables of team dynamics: disparity, culture and composition. We posit a flatter distribution of power and resources (disparity), appropriately varied teams (composition) and feedback-seeking environments (culture) increase a team member's willingness to present dissenting opinions.

Aim: Our investigation aimed to increase our understanding between the relationship of team dynamics, dissent and decision quality within inter-connected, complex teams in high-tempo operational environments.

Method: DSTG analysts administered a 10-minute survey within a military population that measured participant's experiences of team dynamics, their willingness to present dissenting opinions and the perceived quality of decisions made within teams. The survey included published, psychometrically valid questions adapted to be appropriate within military contexts. This adaptation was conducted in consultation with various DSTG, ADF and academic subject matter experts.

Results: Linear regression revealed a significant relationship whereby dissent increased the quality of decisions. Several team dynamics factors were found to have significant relationships with either dissent or decision quality. Role ambiguity (the extent to which team members are unsure of their roles and responsibilities) was found to have a direct negative effect upon their perceived decision quality. A preliminary mediation analysis demonstrated that both psychological safety (the extent to which team members feel they can speak up without reprimand or judgement) and procedural justice (the extent to which team members feel they can influence decision-making processes) positively impact on decision quality through the mediator of dissent.

Conclusions: Our results support a quintessential component of our conceptual model positing that dissent promotes decision quality through enhanced information exchanged. From an organisational perspective, dissent can be promoted through focusing on enhancing dissent-promoting team dynamics such as psychological safety and procedural justice, thereby increase the overall quality of decisions. Additionally, ensuring that members have a strong understanding of their job role (decreasing role ambiguity) represents another means by which decision quality can be improved. Future research will experiment on potential interventions that promote greater dissent and perform further investigations on conceptual pathways between dissent promoting decision quality through reduction of cognitive heuristics and biases.

Modelling and monitoring human operator performance

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Background: In many intelligence and surveillance domains, analysts already have access to more information than they can process in a timely manner. The amount of data that is available continues to expand. The human operator plays a critical role in aggregating and assessing information and using it to update situational awareness and inform decisions. The human-system interaction is a critically fragile component, and there is a limit to how much information a human can process in a given amount of time. Artificial intelligence (AI) offers great promise for assisting human inference and decision making. We envisage a system in which an AI agent augments human capability by scaffolding their inferences through dialogue.

Aim: The aim of this program of work is to develop a framework that meshes behavioural science with artificial intelligence and computational modelling to develop a new approach to human-AI interaction. We conducted an experiment and developed a simple model to establish a proof of concept for this integrated approach.

Method: We devised a task roughly based on a structured Human-Machine Interface (HMI). The "analyst" is required to make a decision or inference for three different tasks that require using information from one or more of the six areas of information within the HMI. Each participant completed three simple tasks, based on representative tasks from the geospatial intelligence domain. Each of the three tasks were completed roughly 100 times, for a total of 300 trials per participant. The experiment was run using custom software written in MATLAB (Mathworks) with routines from the Psychophysics Toolbox [1, 2]. Eye movement data were collected using an EyeLink 1000. These eye movement data were analysed, and saccades and dwell times calculated for each period of time in which the person completed the task. We then used a hidden markov model (HMM) with the three tasks as the hidden states, and the elements in the sequences (the six possible areas of interest) as the emissions. We used a transition matrix that represents a 90% probability of staying on the same task and a 5% probability of moving to each of the other tasks, and we assumed that for each task the possible emissions associated with it were equiprobable.

Results: The model accurately predicted the tasks for each eye track data point over 80% of the time for all 100 different randomisations, with an average accuracy of 82.1%. If we consider between tasks, we find that task 1 had a lower accuracy of around 74%, task 2 a higher accuracy rate 81% and task 3 had the highest accuracy rate of 89.3%.

Conclusions: While a simple example, these data and this simple HMM provide a proof of concept for using this approach to identify task states, and how the human is moving between states.

The findings suggest that the development of a dialogue management system, underpinned by effective inferencing about human tasks, shows promise.

Training and Educational Requirements of Australian Future Autonomous Ship's Operator

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Background: The continual progression of Industry 4.0 adoption across industries has already begun impacting many facets of maritime space including naval construction, operation, personnel, and services (Sullivan et al., 2020). Digitalisation process as the central aspect of Industry 4.0 in marine industry has and will result in employing automation, robotics, and a series of disruptive changes that collectively enhance safety, security, efficiency, and human performance (Shahbakhsh, Emad, & Cahoon, 2021). Moreover, the digitalisation in shipping sectors requires a constant change that leads to modifications in ship's type and sizes, crew competency, traffic management, and transportation routes (Baldauf et al., 2018). This fast-paced introduction of technologies in the marine realm leads the movement toward autonomous ships (Baldauf et al., 2018). The transition from primary human-operated to machine-operated systems has necessitated new ways of thinking (Devitt et al., 2021). Indeed, the tendency of this transition in shipping impacts the crew cognitive and physical performance level, the potential changes to their training, and the development of new capabilities. Subsequently, the level of human-machine interfaces at sea are changing, with new opportunities emerging alongside new technology (Devitt et al., 2021). More importantly, the human is a crucial element of the autonomous system and should be prepared for future challenges and the new roles that will bring (Shahbakhsh et al., 2021). While there is growing research interest in technological areas of autonomous systems, examining the role of the human element in this context is largely neglected and needs to be developed.

Aim: This paper aims to explore the multi-dimensional impact of autonomous systems and robotics technology on human performance in the future operating environment of naval domain.

Method: To address challenges and educational requirements in future autonomous naval systems, this study conducted an in-depth systematic literature review (SLR) to analyse the current research output in this field. The focus is on the human element in autonomous shipping, new roles, responsibilities, educational challenges, and reskilling process of future ships' personnel.

Results: The result of the literature review highlighted the points that there is a myriad of research in the technology of the autonomous systems. These can be classified under eight major categories:

- Autonomous ship navigation concept,
- Deep learning for autonomous ship,
- Cyber security,
- ICT based ship architecture,
- Manoeuvring test,
- Decision-making system,
- Collision avoidance,
- Safety,

However, there is a lack of research on the science of human element in the field of education and training for the future operators of the autonomous ships. In this respect, there is a critical need to fill this gap to assure operators' readiness and enhanced capabilities.

Conclusions: The research concludes with suggestions for future research to fill these gaps. These future research agendas may include:

- Determining skills, competencies, and characteristics of future seafarers,
- Required future training curriculum and facilities,
- Trainers and educators' expertise and proficiencies

References

Baldauf, M., Kitada, M., Mehdi, R., & Dalaklis, D. (2018). E-Navigation, Digitalization and Unmanned Ships: Challenges for Future Maritime Education and Training. Paper presented at the 12th International Technology, Education and Development Conference, Valenica. doi:10.21125/inted.2018.2374

Devitt, S. K., Horne, R., Assaad, Z., Broad, E., Kurniawati, H., Cardier, B., . . . Putland, T. (2021). Trust and Safety, in Robotic Roadmao for Australia V2. In 2104.06512.

Shahbakhsh, M., Emad, G., & Cahoon, S. (2021). The Transitional Role of Seafarers to Autonomous Shipping: A Research Agenda. Paper presented at the 14th International Conference of Asian Shipping and Logistics (ICASL 2021) Seoul, Korea.

Sullivan, B. P., Desai, S., Sole, J., Rossi, M., Ramundo, L., & Terzi, S. (2020). Maritime 4.0 – Opportunities in Digitalization and Advanced Manufacturing for Vessel Development. Procedia manufacturing, 42, 246-253. doi:10.1016/j.promfg.2020.02.078

Digital Twins as a Human-Autonomy Teaming Decision Aid

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Background: Autonomous systems are becoming increasingly important in military missions (Defence Science Board 2016). Systems have been developed to assist war fighters in a range of tasks such as surveillance and reconnaissance, explosive detection and disposals, casualty extraction, supply transportation, building clearing and fire-fighting (Chen & Barnes, 2014). As these systems become more sophisticated, the potential scope for human-autonomy teaming increases and has become an important focus of defence research. Human-autonomy teams are comprised of multiple humans and autonomous systems that work together under conditions of dynamic environments and behaviours by carrying out missions based on general information, automatically adapting to changing circumstances and thinking in higher levels of abstraction. This increase in machine intelligence and associated human-autonomy teaming potentially hinges on the development of machine theory of mind, recursive levels of reasoning and transactive memory systems. The presence of these capabilities, which are central to human cognition, has been shown to improve both human-human and human-machine team performance in coordinated and competitive scenarios by allowing teams to execute missions and coordinate in distributed tactical environments, in situations of denied or degraded communications and in environments where important information is only partially available or absent (Oguntola et al., 2021; Wen et al., 2020 ; Bachrach et al., 2019; Lerer et al., 2019; Devin & Alami, 2016; Milliez et al., 2014; Huang et al., 2013; Lewis, 2004).

Aims: As these capabilities continue to be developed in autonomous systems, the ability for humans to leverage their own theory of mind, recursive reasoning and transactive memory systems when teaming with autonomy is key to effective human-autonomy teaming. A review of current literature will be presented which suggests that interpretability and transparency of autonomous systems are important factors in the human's ability to employ these cognitive capabilities. However, questions still surround the level of transparency necessary to facilitate effective human autonomy teaming. As autonomy grows more complex, further research is required to understand the processes that underpin the ability of humans to understand their autonomous teammates.

Conclusions: A potential avenue through which transparent interpretable autonomy can be facilitated is through digital twins. A digital twin is considered to be an adaptive model of a complex physical system (Rasheed et al., 2019). They are often represented as real time digital representations of physical objects and systems. This representation of the autonomous system serves to make available to the human the capabilities, reasoning process and decisions systems of the autonomy. This in turn assists with the human's ability to employ their theory of mind and reason about the internal states of their autonomous teammates as well as easily and efficiently encode, store and retrieve information from their transactive memory systems. Furthermore, the use of digital twins allows for the exact level of transparency required to facilitate effective teaming to be investigated.

References:

Chen, H., Wen, Y., Zhu, M., Huang, Y., Xiao, C., Wei, T., & Hahn, A. (2021). From Automation System to
Autonomous System: An Architecture Perspective. *Journal of Marine Science and Engineering, 9*(6), 645. https://www.mdpi.com/2077-1312/9/6/645

Chen, J. Y. C., & Barnes, M. J. (2014). Human–Agent Teaming for Multirobot Control: A Review of Human Factors Issues. *IEEE Transactions on Human-Machine Systems, 44*(1), 13-29.
https://doi.org/10.1109/THMS.2013.2293535

David, R. A., & Nielsen, P. (2016). *Defense science board summer study on autonomy*.

Devin, S., & Alami, R. (2016). An implemented theory of mind to improve human-robot shared plans execution. *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, 319- 326.

Huang, Q., Liu, H., & Zhong, X. (2013). The impact of transactive memory systems on team performance.

Information Technology & People, 26(2), 191-212. https://doi.org/10.1108/ITP-04-2013-0068

Lerer, A., Hu, H., Foerster, J., & Brown, N. (2020, 04/03). Improving Policies via Search in Cooperative

Partially Observable Games. *Proceedings of the AAAI Conference on Artificial Intelligence, 34*(05), 7187-7194. https://doi.org/10.1609/aaai.v34i05.6208

Lewis, K. (2004). Knowledge and Performance in Knowledge-Worker Teams: A Longitudinal Study of Transactive Memory Systems. *Management Science, 50*(11), 1519-1533. https://doi.org/10.1287/mnsc.1040.0257

Milliez, G., Warnier, M., Clodic, A., & Alami, R. (2014, 25-29 Aug. 2014). A framework for endowing an interactive robot with reasoning capabilities about perspective-taking and belief management. The 23rd IEEE International Symposium on Robot and Human Interactive Communication,

Oguntola, I., Hughes, D., & Sycara, K. (2021). *Deep Interpretable Models of Theory of Mind For Human- Agent Teaming*.

Rasheed, A., San, O., & Kvamsdal, T. (2019). Digital twin: Values, challenges and enablers. *arXiv preprint*

arXiv:1910.01719.

Wen, Y., Yang, Y., Luo, R., & Wang, J. (2019). Modelling bounded rationality in multi-agent interactions by generalized recursive reasoning. *arXiv preprint arXiv:1901.09216*.

Designing for Agility in an Envisioned Command and Control World: Application of Cognitive Work Analysis to Human-AI Teams

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Background: Analysis of future trends has indicated a shift towards faster, more uncertain, and increasingly novel conflict within the next few decades. To contend with threats present in this envisioned world, the Australian Defence Force (ADF) has identified the need for more agile structures to facilitate rapid and effective adaptation to unpredictable and degraded situations; standing as a significant change from the current hierarchical command and control (C2) structure. Within this context, the integration of agile human-artificial intelligence (AI) teams into the future force has been identified as a key area of development. This concept is known as 'Collaborative Intelligence' (Naikar, Moy, Kwok, & Brady, 2021).

Current AI design is typically based on specific scenarios—an approach which can underestimate the flexibility necessary to operate in contested military contexts and may exclude the advantages of humans in unpredictable situations. Such methods have often led to brittle technology unable to cope with unexpected or rapid situational changes, resulting in low adoption rates of intelligent technologies in the military (Coombs, 2019). The uncertainty and unpredictability of the future contested environment is expected to amplify these effects, necessitating novel design approaches.

Aim: The aim of this work is to design agile human-AI teams that can contend with degraded, evolving, and unexpected situations in the future environment.

Method: We present a novel approach to human-AI team design using Cognitive Work Analysis (CWA). Unlike traditional methods, CWA outlines the system in terms of its constraints, or boundaries on successful action. As such, prescribed 'success' routes remain undefined and actors are free to choose from many credible possibilities within the system boundaries; intrinsically weaving agility through the design. Importantly, this analysis also defines the system independently of specific actors so that both human and artificial intelligence are accommodated, and tasks can be fluidly distributed.

As a first step, analysis of authoritative documents and subject matter expert interviews were conducted to extract key characteristics of the envisioned world. Using this description, the first dimension of CWA, Work Domain Analysis (WDA), was applied to begin outlining the fundamental constraints of a C2 system.

Results: Extraction of key challenges in the envisioned world resulted in a textual and graphical description, which succinctly defines the necessary context for future designs. The work domain model provides a novel framework and visualisation onto which ADF C2 elements can be mapped, and defines one dimension of constraints to which the C2 system and consequent collaborative intelligence teams must adhere.

Conclusions: This research crystalises the potential challenges in the future environment and defines the fundamental context for eliciting design requirements for human-AI teams. As the boundaries identified are independent of situation or specific hardware, they are globally applicable to ADF C2 elements and facilitate less brittle design by preserving environment unpredictability and flexibility of action. The level at which the WDA has been developed also allows it to be widely applied as an aid

in Agile C2 analysis. Moreover, this approach can be extended for application in design of technologies other than human-AI teams.

References:

Coombs, G. (2019). *A review of intelligent decision support systems for land tactical planning*. DSTG Technical Note (DST-Group-TN-1921). Defence Science & Technology Group.

Naikar, N., Moy, G., Kwok, H., & Brady, A. (2021). Designing for "Agility" in an Envisioned Command and Control World: Concepts for Collaborative Intelligence in Human-Machine Teams. *Proceedings of Naturalistic Decision Making and Resilience Engineering Symposium*. Toulouse, France.

Trait-level Cognitive and Psychological Factors Associated with Resilience to Sleep Disturbance during COVID-19

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Background: The negative impact of the COVID-19 pandemic on sleep quantity and quality has been well established through multiple meta-analyses. For example, reviewing 179 papers from 39 countries, Alimoradi et al (2021) reported the prevalence of sleep problems assessed with validated measures to be 37% of the general population. This number was much higher during lockdowns (46%) and when studies utilised a longitudinal design (62%). The stress of the pandemic and associated lockdowns, and uncertainty related to health and financial wellbeing contribute to these sleep difficulties (Cox et al, 2021). However, not everyone reports poor sleep, and few studies have sought to identify potential protective factors.

Aim: To examine trait-level cognitive and psychological factors that may be associated with resilience to the sleep disrupting effects of the COVID-19 pandemic.

Method: 628 individuals [526 (83.8%) females, age: 39.1±17.2 years; 129 ethnic/racial minority (20.5%)] from the USA participated in an online study during the early phases of the pandemic (20 March – 30 June, 2020). They completed 60 consecutive days of sleep diaries, as well as four trait measures: Brief Self Control Scale, Intolerance of Uncertainty, Emotion Regulation Questionnaire (2 subscales), and Short Impulsive Behavior Scale (5 subscales). We examined the association of each trait measure with the mean and variability over time in three sleep outcomes: 1) sleep opportunity (time-in bed, TIB: the amount of time spent attempting to sleep during the major sleep episode); 2) sleep quantity (total sleep time, TST: minutes of sleep during the major sleep episode); and 3) sleep quality (sleep efficiency, SE: % of time spent asleep during the major sleep period). Analyses consisted of mixed effects models with random intercepts and slopes.

Results: Greater self-control, greater perseverance (subscale of impulsivity), and lower positive urgency (acting impulsively when experiencing strong positive emotions) predicted lower variability in all three sleep measures. Greater self-control also predicted greater mean TST and SE, while greater perseverance predicted mean TST and TIB. Other trait measures predicted 0-2 of the six sleep measures.

Conclusions: The trait measures we assessed were more strongly associated with sleep variability over time than with average sleep over time. Of those measures, higher levels of self-control and perseverance, and lower positive urgency were most strongly associated with sleep, especially sleep efficiency. It appears these cognitive constructs may serve as protective factors, whereby high levels in the "good" direction confer resilience against the negative changes to sleep widely reported during the pandemic. Resilience against increased sleep variability is critical, given variability has been associated with a variety of poor mental and physical outcomes. Interestingly, these constructs have recently been proposed as part of a suite of cognitive traits underlying optimal cognitive performance across various applied settings (Aidman, 2020). Our findings suggest they may also relate to how individuals regulate sleep during a chronic, pervasive, societal-level stressor. Training programs aimed at bolstering these traits may help build resilience to future systemic stressors.

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References:

Aidman, E. Cognitive Fitness Framework: Towards assessing, training and augmenting individual- difference factors underpinning high-performance cognition. Frontiers in Human Neuroscience. 2020, 13:466. doi: 10.3389/fnhum.2019.00466.

Alimoradi, Z, Brostrom, A, Tsang, HWH, Griffins, MD, Haghayegh, S, Ohayon, MM, Lin, C-Y, Pakour, AH. Sleep problems during COVID-19 pandemic and its associations to psychological distress: A systematic review and meta-analysis. EClinicalMedicine. 2021, 36:100916. https://doi.org/10.1016/j.eclinm.2021.100916.

Cox, RC, Olatunji, BO. Sleep in a pandemic: Implications of COVID-19 for sleep through the lends of the 3P Model of insomnia. American Psychologist. 2021. https://doi.org/10.1037/amp0000850.

The Timing of Daytime Sleep can be used Strategically to Manipulate the Response of the Internal Body Clock to Night Work.

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Aim: The aim of the study was to examine the influence of the timing of sleep, and thus the timing of daytime light avoidance/exposure, on circadian adaptation to a week of night work. It was hypothesised that night work would delay the circadian system – and the size of the delay would increase as the duration of exposure to morning and early-afternoon light decreased.

Method: Forty-three adults (21F, 22M) were randomly assigned to one of four conditions in a laboratory-based simulated night work protocol. Each condition included seven consecutive 8-hour night shifts (23:00–07:00h). The only difference between conditions was in the timing of the 7-hour sleep opportunities in breaks between shifts. The conditions, in order of increasing exposure to light in the morning and early-afternoon, were: Morning Sleep (08:30–15:30h), Split Sleep #1 (08:30–13:30h and 19:30–21:30h), Split Sleep #2 (08:30–10:30h and 16:30–21:30h) and Afternoon/Evening Sleep (14:30–21:30h). Circadian phase, or body clock time, was assessed on the nights immediately before and after the week of night work using hourly saliva samples to determine the timing of dim light melatonin onset (DLMO). If an intervention, such as night work, causes DLMO to shift to a later time, that is referred to as a delay in the timing of the body clock, or 'phase delay'. Conversely, if an intervention causes DLMO to shift to an earlier time, that is referred to as an advance in the timing of the body clock, or 'phase advance'. Light intensity was 75 lux during night shifts, <0.03 lux during sleep, <10 lux during DLMO assessments and 350 lux at other times.

Results: The DLMO data were analysed using a mixed-design ANOVA with one within-subjects factor (time: two levels – before and after the week of night work) and one between-subjects factor (condition: four levels – Morning Sleep, Split Sleep #1, Split Sleep #2, Afternoon/Evening Sleep). There was a significant interaction ($F=10.6$, $df=3,39$, $p<.0001$), such that the pre/post change in the timing of DLMO differed between the conditions. Specifically, Morning Sleep caused a delay of 5.06±2.11 hours, Split Sleep #1 caused a delay of 2.58±2.46 hours, Split Sleep #2 caused a delay of 1.30±2.62 hours and Afternoon/Evening Sleep caused an advance of 0.71±2.84 hours.

Conclusions: These data indicate that the timing of daytime sleep, and thus the amount of exposure to light in the morning and early-afternoon, substantially affects the extent to which the internal body clock adapts to a week of night work. Furthermore, the data indicate that the timing of sleep can be used strategically to manipulate the internal body clock's response to night work. In situations where defence personnel wish to maximise adaptation to night work, e.g., if night work must be sustained for several days or weeks, then sleep should occur in the morning. Conversely, in situations where defence personnel wish to minimise adaptation to night work, e.g., if night work is only required for one or two days, then sleep should occur in the afternoon/evening.

The influence of variability in bed and wake times on quality of sleep in elite athletes

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Background: The importance of optimal sleep is becoming increasingly recognised for optimal performance, health and wellbeing. Calculation of the daily variation around the mean, or simply, sleep regularity, is becoming increasingly popular in sleep science research. High variability in night-to-night sleep has been shown to be related to poor quality sleep, subjective sleep complaints and insomnia. Daily intraindividual variability of sleep/wake patterns are associated with important physical and mental health outcomes. These include higher body mass index, weight gain, bipolar or depression symptomology, stress, symptoms of insomnia and poor sleep.

Aim: The aims of this study were to 1) determine the effect of regular versus irregular sleep on sleep characteristics, 2) identify the contributors to sleep efficiency and sleep duration, 3) describe the effects of night-to-night variability on subsequent sleep and 4) provide summary data to optimise sleep strategies.

Method: Sleep was monitored over a minimum of 7 days in 287 athletes providing a total of 2,009 nights of sleep. Participants wore a wrist activity monitor and completed self-report paper sleep diaries to monitor sleep/wake behaviour. Sleep duration and sleep efficiency were used as outcome variables. Variability in sleep behaviour was assessed through the sleep regularity index (SRI) was calculated to reflect the night-to-night shifts in sleep cycles by accounting for changes in bedtime and waketime and aggregated for the week. Night-to-night shifts in bed and waketimes were also calculated for bed and waketimes. The influence of SRI on sleep efficiency and sleep duration was assessed via linear regressions. For nightly bed and waketime variability, generalised estimating equations were used.

Results: Regular sleepers went to bed earlier than irregular sleepers and, on average, displayed minimal variation in bed (7 [0 to 14] minutes) and waketimes (-2 [-10 to 8] minutes). Sleep variability behaviour had poor predictive performance on sleep efficiency, explaining 9% of variance in efficiency. Despite this, SRI was the most important predictor of sleep efficiency. For sleep duration, SRI had no influence, earlier bedtimes and later waketimes were important predictors, with sleep variability behaviour explaining 90% of the variance in sleep duration. Nightly variability in sleep behaviour revealed small, but significant relationships for reductions in sleep efficiency with a later morning waketime and later bedtime. Sleep duration was also reduced when athletes woke later in the morning, went to bed later that night.

Conclusions: To optimise quality of sleep, bedtimes should be kept as regular as possible. To optimise quantity of sleep, sufficient time in bed in necessary. Support staff can assist by providing schedules that allow for both regularity and sufficiency of time in bed, with the aim of protecting sleep wherever possible.

The Role of Established and Newly Proposed Cognitive Fitness Constructs in Compliance with COVID-19 Protective Measures and Psychological Recovery: A Validation Study

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Abstract:
Background: The Cognitive Fitness Framework (CF2; Aidman, 2020) has evolved into an expert consensus on core psychological constructs underpinning optimal performance in Defence and other high-pressure settings (Albertella et al., 2021). The COVID-19 pandemic has escalated the importance of these constructs to the general public and created a unique opportunity to examine how they shape individual behaviours in stressful, dynamic, and uncertain environments. We surveyed self-reports on Cognitive Primaries (e.g., impulse- control) and Tolerances (resilience/adaptability) during the first wave of the pandemic. We also developed a new scale—COVID-19 Character Growth Awareness (COVID-19 CGA) capturing reflections of character growth following challenges faced. We assessed thriving and recovery during the pandemic with Mental Well-being (MWB), Mental Well-being Recovery and Compliance Attitudes metrics.

Method: Survey data were collected in July-August 2020, when Australian national restrictions were eased everywhere except Victoria. This enabled us to examine the hypotheses of interest focusing on the cognitive fitness constructs and processes within the 'recovery' period while being acutely ready for the possibility of escalated restrictions. The survey also included a comprehensive selection of measures capturing the most salient aspects of one's ecological system, demographics, and individual differences. We controlled for social desirability to partial out this pervasive response bias.Sample: A representative Australian sample of 417 participants (age of 34.38; 48.7% female) were recruited via Prolific to complete an online survey. The sample captured a representative range of states, ages, genders, occupations, educational levels, incomes, physical/health characteristics, and social support.

Results: Three regression models were conducted predicting: 1) Compliance Attitudes; 2) Mental Well-being; and 3) Perceived Mental Well-being Recovery. The role of the CF2 constructs was considered above and beyond essential demographic and situational factors, attitudes and social desirability. The models predicted about 46% of variance in Compliance Attitudes, about 57% in MWB, and about 15% in MWB Recovery. While Resilience/Adaptability was a positive predictor of the Compliance Attitudes and MWB, Impulsivity/Lack of Self-control was a negative predictor of MWB. The newly developed measure of COVID CGA had excellent psychometrics properties and was the only measure that predicted all three positive adaptation metrics, and it was one of the strongest predictors of MWB and its recovery.

Conclusions: The findings support the important utility of CF2 constructs, impulsivity/lack of self-control and resilience/adaptability, as well as the newly proposed character growth awareness construct during the unique natural experiment presented by COVID-19. The emerging importance of the personal growth awareness construct, as a proof of concept, helps to unify the theory of resilience, as a trait, process, and outcome. While this research was not focused on operational task performance, there are lessons to be learned about the constructs proposed to facilitate positive adaptation during crises. These lessons can be integrated into the CF2 framework and tested with military personnel facing extended challenges during training and operations. Preliminary findings indicated that the construct of character growth awareness during crises is a viable candidate for further development, validation, and potential inclusion into the CF2 model.

P3R - Impact of a pre-conditioning program on training outcomes in female Army recruits

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Background: A barrier for many females attempting to enlist into the Australian Army is achieving the pre-enlistment fitness assessment (PFA) standard. To mitigate this, Army has introduced a pre- conditioning program immediately prior to the Army Recruit Course (ARC) for female applicants who satisfied all enlistment criteria except for physical fitness. With a minimum duration of 7 weeks, the Army pre-conditioning program (APCP) is focused upon developing the fitness of female recruits to achieve the PFA standard and enable commencement of the ARC. A recent evaluation of APCP outcomes indicates a success rate of ~82% since the program began in 2016 (Drain, Larsen et al. 2021). However, it is unclear whether APCP graduates achieve similar ARC training outcomes to female recruits who enter the ARC directly.

Aim: Characterise the training outcomes in female recruits who undertook the APCP prior to the ARC (APCP+ARC) compared with females who entered the ARC directly (ARC-direct).

Method: A prospective cross-sectional investigation was undertaken to compare training outcomes between APCP+ARC and ARC-direct. Data was collected from recruits who commenced training at the Army Recruit Training Centre, Kapooka between February 2019 and March 2020. Physical performance (beep test predicted VO2max, push-ups, isometric mid-thigh pull, standing broad jump) was assessed during weeks 1, 2 and 8 of the ARC. Musculoskeletal injuries and graduation outcomes (marched out, discharged) were obtained from records at the Army Recruit Training Centre. Study procedures were approved by the Departments of Defence and Veterans' Affairs Human Research Ethics Committee (protocol number: 051-18).

Results: A total of 136 APCP+ARC recruits (age 23.5±6.6 y, body mass 68.2±10.3 kg, predicted VO2max 39.7±2.2 mL/kg/min) and 277 ARC-direct recruits (age 22.3±6.0 y, body mass 64.7±8.8 kg, predicted VO2max 39.2±2.8 mL/kg/min) consented to participate in the study. There were no differences in baseline characteristics between groups ($p>0.05$), except for body mass ($p=0.001$) and standing broad jump with ARC-direct recruits demonstrating greater performance (171±25 vs 151±21 cm, $p=0.000$). At week 8, ARC-direct recruits demonstrated greater predicted VO2max, push-ups, and standing broad jump. APCP+ARC recruits only improved performance in isometric mid-thigh pull and box lift; however the magnitude of improvement was modest (~6-10%) compared with the ARC- direct females (~12-17%). Graduation success was 84% and 89% for APCP+ARC and ARC-direct recruits respectively ($p=0.151$); the remainder of recruits were discharged. For those recruits that graduated, there was no difference in weeks in training between groups (13.2±4.1 vs 13.2±3.7, $p=0.99$). Similarly, there was no difference between groups in the number of recruits who sustained at least one musculoskeletal injury (22.8 vs 23.8%, $p=0.82$).

Conclusions: While APCP+ARC recruits demonstrated limited gains in physical fitness compared with recruits who entered the ARC directly, there were no differences between groups in graduation success or injury. Current evidence indicates that APCP provides an effective pathway for increasing

ARC throughput for female recruits. However, it remains to be seen whether both groups will experience similar outcomes during trade-specific training and once in the trained workforce.

References:

Drain, J., P. Larsen and H. Groeller (2021). Prospective Physical Performance and Resilience (P3R) Study: Evaluation of the Army Pre-Conditioning Program for Females, 2016–2020. Melbourne, DSTG-TN-2126, 38 pg.

Exploring changes in the host gut microbiota during a controlled human infection model for Campylobacter jejuni

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Campylobacter jejuni is associated with 7.5 million disability-adjusted life years globally, and is a leading cause of foodborne disease in the United States. Additionally, it is a leading cause of travelers' diarrhea, particularly in Southeast Asia. For deployed military populations, the pathogen represents an important infectious disease threat for which primary prevention is needed. One method that offers an early assessment of potential products for *C. jejuni* prevention is the controlled human infection model (CHIM) in which a known dose of a well characterized organism, such as *C. jejuni*, is administered to susceptible subjects in a well controlled environment. We previously utilized a CHIM to determine if prophylactic administration of the antibiotic rifaximin prevented campylobacteriosis. This study also provided an opportunity to observe the response of the total host gut microbiome utilizing 16S rRNA gene sequencing under chemoprophylaxis and when challenged by *C. jejuni* under highly controlled conditions with multiple temporal samples. After removing an outlying sample, placebo recipients showed no difference in the relative abundance of *C. jejuni* compared to subjects given rifaximin. The relative abundance of *C. jejuni* was also not correlated with symptom presentation or severity. *C. jejuni*- treated subjects that did not meet the clinical definition of moderate to severe diarrhea had a decreased relative abundance of the Bacteroides and an increase in the relative abundance of the *Ruminoclostridium* prior to pathogen challenge. These results suggest a tantalizing potential protective effect of microbial communities, and point to potential targets for future probiotic study.

Interaction in virtual environments

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Background: Virtual reality (VR) technologies are increasingly being employed for training, mission rehearsal and teleoperation. The current generation of consumer VR technologies have good visual displays with low latency, but the presentation of haptic (tactile and proprioceptive) cues is not well supported, limiting visuomotor interaction with the environment. It has recently been suggested that interaction in a virtual environment may be facilitated if operators are able to embody their virtual effectors (Toet et al., 2020).

Aim: This study examined the role of different haptic cues in supporting efficient interaction with the environment. It also investigated the role of perceived embodiment of the virtual effectors in supporting interaction.

Method: Twenty participants performed an ISO Standard Fitts' tapping task under five conditions (real environment, and VR with hybrid haptics, passive haptics, active haptics, and no haptics) that ordinally degraded visual and haptic cues. Passive haptics provided veridical tactile and proprioceptive cues, while active haptics provided only abstract tactile cues. Hybrid haptics simulatedan ideal passive haptic display. Perceived embodiment of virtual effectors was evaluated by a subjective questionnaire.

Results: Visuomotor performance (throughput) was lower in the conditions with degraded cues. The VR conditions with higher performance also had higher ratings of perceived ownership, control and realism of touch of the virtual effectors. Of these, only realism of touch predicted significant unique variance in throughput.

Conclusions: Passive haptic interfaces support efficient interaction as well as a sense of ownership, control and realism of the virtual effectors. However, this study provided little support for thehypothesis that visuomotor performance is mediated by embodiment of virtual effectors. Passive haptics are suitable where object locations are in stable and known locations, such as aircraft cockpits.

References:

Toet, A., Kuling, I. A., Krom, B. N., & Van Erp, J. B. (2020). Toward enhanced teleoperation through embodiment. Front. Robot. AI 7: 14.

The Effects of Decision Aid Presentation on Decision-Making in a Multi-Cue Signal Identification Task

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Abstract:

Background: Decision-making in complex environments can be challenging, with humans required to integrate information from different sources quickly and accurately. These environments often require decisions to be made based on multiple cues, each with some degree of uncertainty. Humans tend to have difficulty making decisions under these conditions, often falling well short of optimal performance. Similarly, humans are poor at incorporating base-rate information in their decision- making and human identification judgements have been found to tend towards unbiased decision- making, even when base-rates suggest that they should be biased towards events that are more likely. Automated decision aids are commonly used to assist humans in integrating base-rate and cue information in a manner that is statistically ideal, reducing the task demands of the human. However, such autonomous decision aids are not always accurate, and the responsibility for judgement may fallon the human. Consequently, an important aspect of human-machine collaborations is that users havea calibrated trust in technology; such that they can appropriately rely on the decision aid to achieve their goals in uncertain conditions. One factor affecting trust in automation is how decision aids present information to operators. Decision aids can be presented in several formats, and research into the display of decision aids has led to a widely shared belief that there is no single optimal format to best support humans making decisions. Two of the most common types of presentations are graphicaland numerical formats. Much research has examined the impact of graphical and numerical presentations of information, noting that decision-makers use different strategies when presented withdifferent decision aids, but the literature lacks clarity over the conditions surrounding their effectiveness.

Aim: To determine how to best present decision aiding to support humans in making quick and accurate decisions in a multi-cue environment with multiple event base rates. This research also aimsto understand the relationships between aid presentation, trust, and workload.

Method: Participants completed a three-alternative forced choice signal-identification task that required them to integrate readings displayed across a set of three gauges which updated over time. The base rates of the signal categories were unequal, with civilian signals occurring at a higher rate than friendly and hostile signals, meaning a biased response criteria was required for optimal decision-making. Participants experienced the task in three conditions: unaided, using a numerical decision aid, or using a graphical decision aid. The decision aids combined the gauge and base rate information in a way that was statistically optimal, updating dynamically by accumulating past and present gauge readings, and calculated the probability of each of the three signal categories. These probabilities were presented as an integer percentage in the numerical aid format, and as a bar graphin the graphical aid format. Following each condition, participants indicated how much they trusted the aid and how hard they worked during the task.

Results: Data collection is underway and initial analyses are expected to have been performed by the time of the conference.

The effects on cognitive performance of apparel fibre type and task complexity

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Background: Human cognitive performance has been shown to be sensitive to heat, humidity and temperature conditions (Yeganeh, et al., 2018). One aspect of maintaining peak cognitive performance involves the ability to accurately and effectively regulate body temperature and maintainphysical comfort. Prior studies utilizing Montreal Imaging Stress Test (MIST) have shown that a prefrontal cortex (PFC)-hippocampus-amygdala circuit mediates endocrine and autonomic stress responses. Merino wool garments have been shown to offer improved breathability over similar polyester garments (Holcombe, 2009).

Aims: The aims of this rapid pilot project were to assess the effects on cognitive performance of: a stress induction protocol; and of using either wool or polyester upper-body apparel during the stress induction task.

Method: Participants were randomly assigned to the wool or synthetic garment condition. All participants completed MIST to induce a stress response. This task is designed to impose cognitive load and evaluative anxiety on the participant (Dedovic, et al., 2005). Participants were asked to solve arithmetic problems of 5 different difficulty levels under 3 different stress conditions (in counter balanced order). Participants also completed the Psychomotor Vigilance test and the Inspection Time test. Their heart rate and facial expression were monitored during the tests and used to determine physiological regulation of the stress response.

Results: There were significant main effects on performance across condition (level of induced stress) and of garment fibre type. The results of this rapid pilot study demonstrate that MIST is a validand reliable method for testing the effects on cognitive performance of both induced stress and garment fibre type.

Conclusions: By careful measurement and control of extraneous variables, and using a fully controlled within-subjects manipulation of stress, we observed a difference in the proportion of accurate responses across the control and experimental conditions and a small but statistically reliable effect of textile type. A larger sample may further show the extent of these effects.

Key implications: Performance of complex cognitive operations (such as those used in this study) tend to be sensitive to the impact of stressors than more simple cognitive operations. Differences in garment breathability may influence environmental stressors. It is important to use a combination of sensitive tests and physiological measures to understand the parameters of cognitive fitness.

References:

Yeganeh, A.J., Reichard, G., McCoy, A.P., Bulbul, T., & Jazizadeh, F. (2018). Correlation of ambient air temperature and cognitive performance: A systematic review and meta-analysis. Building and Environment, 143, 701-716.

Dedovic, K., Renwick, R,, Khalili Mahani, N., Engert, V., Lupien, S.J. & Pruessner, J.C. (2005). The Montreal Imaging Stress Task: using functional imaging to investigate the effects of perceiving and processing psychosocial stress in the human brain. J Psychiatry Neurosci, 30, 319- 325.

B. Holcombe (2009). Wool performance apparel for sport. Advances in Wool Technology, Ed. N.A.G Johnson & I.M. Russell, Woodhead Publishing, 265.

Artificial Intelligence based Smart Technology for Engineering Education Training

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Background: Engineering education institutes can leverage various emerging technologies to transform laboratories that provide students through practical education and professional development programs. Technology plays an essential role in imparting education, assisting students in studying new disciplines, and improves student understanding of complex ideas, particularly in Science, Technology, Engineering, and Mathematics (STEM). In Engineering laboratories, students put theoretical knowledge into practice to become professional engineers who can resolve global technological issues.

Unfortunately, many students have access to labs equipped with expensive equipments only for brief and limited periods of time (Odeh, 2012). Furthermore, the COVID-19 pandemic also moved laboratory experiments away from campuses by delivering kits to students, posing various challenges for practical education. To circumvent the laboratory challenges, this research study incorporates Augmented Reality (AR) and Machine Learning (ML) algorithms using smart glasses to enhance procedural demonstrations to students off-campus. In addition, AR smart glass serves as an on-the-go instructor, ensuring that every student receives the same clear guidance for lab assignments, thereby reducing errors and improving student's decision-making and technical skills required to complete lab activities off-campus.

Aim: The aim of this research study is to identify the challenges of physical laboratories, explore how physical labs can be digitalised, and develop smart technology to facilitate students in completing their lab activities. The study proposes adopting Augmented Reality (AR) smart glasses and identifying Machine Learning (ML) algorithms to provide remote assistance to engineering students who are undertaking laboratory activities to improve their competencies, decision-making, and technical capabilities.

Method: As part of this research study, an online survey was developed and will be conducted on engineering students to evaluate the challenges they encounter while performing laboratory activities and analyses their attitudes towards the use of Augmented Reality smart glasses in laboratories. Additionally, a Machine Learning model will be developed and trained using data collected through smart glasses. Smart glasses enable students to take photos and capture videos while experimenting in laboratories. The collected images will be labelled and sent to a server. Our Machine Learning model will then detect and predict whether engineering students make appropriate decisions and complete their laboratory activities successfully. If the students perform any mistakes, the model will show a warning message instructing them to correct the mistakes.

Conclusions: The research is currently in an advantageous position to leverage the recent technological advancements in Augmented Reality and Machine Learning space in providing an education system with tools to outperform the students learning process. As a result, Artificial Intelligence-based smart technology will be developed to offer a risk-free method for engineering students in laboratory training instead of the traditional methods. It also assists students in acquiring the equipment knowledge necessary to undertake practical tasks. Consequently, it strengthens the engineering laboratory learning approach away from campus and equips students with the professional skills necessary to overcome obstacles in various scenarios.

References:

Odeh, S., Shanab, S.A., Anabtawi, M. & Hodrob, R. (2012). Remote augmented reality engineering labs. In *Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON),* 1-6.

Improving the measurement of attentional conflict resolution

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Background: Defence-force personnel must sustain optimal performance under pressure. In a transdisciplinary Delphi study (Albertella et al., 2021) the RDoC "attention" construct was selected as a key cognitive systems capacity enabling optimal performance. One of the principle attention components required for high performance is resolving response conflicts by selectively attending to relevant information and inhibiting irrelevant information. This is measured in a range of "conflict" tasks where the irrelevant information comes from the automatic habits (reading in the **Stroop** task, e.g., name the print colour of "GREEN"; MacLeod, 1991), the locations of the decision stimulus (the **Simon** task, e.g., when a signal occurring on the left requires a right-hand response, Hommel, 2011) or visually adjacent stimuli (e.g., the **Flanker** task, which direction does the central arrow point "<<><<"; Eriksen, 1995). Unfortunately, over the last few years it has become accepted that reliable measurement of individual differences in these tasks requires participants to complete many more trials and/or to use tasks with larger effect sizes than are typical of existing cognitive batteries (Hedge et al., 2018a).

Aim: We aimed to develop new versions of conflict tasks that enable reliable measurement with fewer trials.

Method : We developed Flanker and Simon tasks, combined Flanker and Simon and Stroop and Simon tasks, and versions of these tasks requiring participants to make a second response based on the irrelevant information on 1-in-3 trials in the UNITY video-game environment. We ran two experiments on the Mechanical Turk platform (n=432 and n=670 respectively) to refine and assess these tasks.

Our analysis used hierarchical models (Rouder & Haaf, 2019) that enable valid measurement of the ratio of two standard deviations (g) that is critical for the reliability of individual differences:

$$g = \frac{SD_{ID}(CE)}{SD_{MN}(n)}$$

ID = Individual Differences; CE = Conflict Effect = $RT_{Incongruent} - RT_{Congrent}$
In/congruent = Relevant & irrelevant Information mis/match
RT = Response Time; MN = Measurement Noise;
n = Incongruent + Congruent trials

We assumed reliable measurement requires SD_{ID} to be at least half the standard error of measurement (r=1/2), requiring a minimum trial number (Rouder et al., 2019):

$$n_{min} = \left(\frac{2}{rg}\right)^2$$

We compared our results to those from standard Flanker (Hedge et al., 2018a) and Simon (Hedge et al., 2018b) tasks.

Results: The second-response Flanker condition (CE=0.222s; g=0.63, n_{min}=63) improved markedly over the standard Flanker (CE=0.039s; g=0.149, n_{min}=721). The second-response Simon condition (CE=0.075s; g=0.306, n_{min}=266) was also improved (standard: CE=0.1s, g=0.123, n_{min}=1052).

The smaller Simon effect added little to the larger Flanker and Stroop components. Even in our best-performing conditions, as individual differences in the sum of both conflict effects increased measurement noise increased more quickly, resulting in less reliable measurement (Flanker +Simon: CE=0.217; g=0.423, n_{min}=140; Stroop+Simon: CE=0.14; g=0.455, n_{min}=126)

Conclusions: We found that, relative to standard versions, combining a video-game format and having participants occasionally make a second response that required them to process the irrelevant information reduced the number of trials required for reliable measurement in the Flanker task by a factor of 11, and in the Simon task by a factor of 4. Double-conflict tasks were not found to increase effectiveness over these results.

References

Albertella, L., Kirkham, R., … Aidman, E., & Yücel, M. (2021). Building a Transdisciplinary Expert Consensus on the Neurocognitive Drivers of Performance Under Pressure: An International Delphi Study, Manuscript in preparation.

Eriksen, C. W. (1995). The flankers task and response competition: A useful tool for investigating variety of cognitive problems. *Visual Cognition*, *2*(2-3), 101–118.

Hedge, C., Powell, G., & Sumner, P. (2018a). The reliability paradox: Why robust cognitive tasks do not produce reliable individual differences. *Behavioral Research Methods*, *50*(3), 1166–1186.

Hedge, C., Powell, G., Bompas, A., Vivian-Griffiths, S., & Sumner, P. (2018b). Low and variable correlation between reaction time costs and accuracy costs explained by accumulation models: Meta-analysis and simulations. *Psychological Bulletin*, *144*(11), 1200–1227.

Hommel, B. (2011). The Simon effect as tool and heuristic. *Acta Psychologica*, *136*(2), 189–202.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin*, *109*(2), 163–203.

Rouder, J. N., & Haaf, J. M. (2019). A psychometrics of individual differences in experimental tasks. *Psychonomic Bulletin & Review*, *26*(2), 452–467.

Rouder, J., Kumar, A., & Haaf, J. M. (2019). Why most studies of individual differences with inhibition tasks are bound to fail. https://psyarxiv.com/3cjr5/

Future Force: Enhancing Shipbuilding Operations with Exoskeletons

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Background: Maritime operations are largely conducted with sea-going vessels that are increasingly sophisticated in their design and capability. The construction of these maritime assets is resource intensive and often requires long timelines. In shipyard operations, workers undertake activities requiring skill and precision in the fabrication of structures and components.

Naval Group, with a global workforce of more than 15,000 employees, designs, produces and supports submarines and surface ships and also provides services for naval shipyards and bases. As the international design and build partner for Australia's Future Submarine Program, Naval Group will play a critical role in the construction and delivery of 12 world-leading, regionally superior Attack class submarines. Naval Group Pacific has established a collaborative framework with Flinders University in Adelaide that will inform future capability for Australia. One of Naval Group's goals is to continually improve its operations, processes, fabrication methods, and operator working conditions.

Aim: This work investigated the utility of upper limb passive exoskeletons in selected shipbuilding trades to inform future shipyard operations with a view to incorporating assistive devices in the conduct of tasks undertaken. In particular, this study sought to examine potential consequences of the intervention in the workplace of assistive devices and their effect on both operator and organisational effectiveness and productivity.

Method: Using authentic use cases of activities undertaken in European shipyards, ergonomic analyses were undertaken to investigate the effective use of this assistive technology. Laboratory based simulation environments were constructed and representative tasks modelled on the Use Cases were designed. Operators were provided with a set of activities that were monitored and a variety of measures including physiological characteristics, task performance and technology acceptance were taken. Additionally, the team participated in an international standardisation body, Association Française de Normalisation (AFNOR), which is working towards developing standards for the use of exoskeletons in industrial settings. Flinders University is the only non-European member on AFNOR, which is significant in leadership and collaboration with industry towards the use of exoskeletons in the workplace.

Conclusions: This study has important implications not only for shipbuilding but in other Defence settings such as sustainment and aerospace construction: with relevance for Navy, Army and Air Force stakeholders. As work-related musculoskeletal disorders and decreased productivity can occur when there is a mismatch between the physical requirements of the task and the operator's physical capacity, the use of assistive devices may help to mitigate this risk. The main risk factors are body posture, exertion, repetition and duration. In addition, improved performance and productivity can result from properly targeted intervention using assistive devices. However, the intervention of assistive devices in the workplace requires consideration of consequential changes to the way operators carry out their tasks and organisations carry out their enterprise. Both short term and longer term considerations should be considered in the "whole-of-capability" results (both operator and business enterprise) of such an intervention. With proper consideration of not just the operator, but also the broader organisational changes, significant benefits can be achieved in lowering risk and improving productivity.

References:

Maurice *et al*. (2020). Objective and Subjective Effects of a Passive Exoskeleton on Overhead Work. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, Vol 28 No 1, 152-164.

Schmalz *et al*. (2019). Biomechanical and Metabolic Effectiveness of an Industrial Exoskeleton for Overhead Work. *International Journal of Environmental Research and Public Health*, Vol 16 No 23.

McFarland, T. & Fischer, S. (2019). Considerations for Industrial Use: A Systematic Review of the Impact of Active and Passive Upper Limb Exoskeletons on Physical Exposures, *IISE Transactions on Occupational Ergonomics and Human Factors*, Vol 7 No 3-4, 322-347.

Theurel, J. & Desbrosses, K. (2019). Occupational Exoskeletons: Overview of Their Benefits and Limitations in Preventing Work-Related Musculoskeletal Disorders, *IISE Transactions on Occupational Ergonomics and Human Factors*, Vol 7 No 3-4, 264-280.

Improving military pilot training through an unobtrusive eye-tracking system

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Background: Between 2018 and 2020, Seeing Machines was engaged in a Jericho Dawn (18-8) program with the Commonwealth of Australia to deliver a research outcome surrounding the use of aneye-tracking system (Crew Training System; CTS) and the degree with which it would benefit Qualified Flying Instructors (QFI) and enhance the training outcomes of pilot candidates in an operational training environment. Despite the promise of eye-tracking for pilot training, no research existed to show that providing flight instructors with objective, real-time eye movement data from trainees can improve training outcomes in an operational training setting.

Aim: This Jericho Dawn research was conducted in an operational training context with actual pilots- in-training. In addition to exploring differences between experts (i.e. QFIs) and less-experienced pilots (i.e. Introductory Fighter Course trainees), this research tested whether presenting information on the precise eye movements of pilots could help Qualified Flying Instructors to determine pilot proficiency.

Four specific hypotheses were targeted:
H1. CTS will improve instructors' awareness of trainees' scanning behaviour
H2. CTS will enable instructors to improve trainee pilots' scan quicker than current methodsH3. Recordings of in-scenario CTS can be used as an effective debriefing tool with trainees H4. CTS will help instructors to determine the proficiency level of pilots

Method: CTS was temporarily installed in the Hawk 127 Full Mission Simulator (FMS) at RAAFBase Pearce (79 Squadron).

Two different Introductory Fighter Courses were used for data collection. Each course had betweenthree and five trainees, and involved approximately eight QFIs across both courses.

To address hypotheses 1-3 a control group and an experimental group were utilised. This afforded a robust experimental comparison between current training methods (i.e., a 'baseline') and training withthe aid of CTS.

To address hypothesis 4, CTS recordings of standard flight manoeuvres were gathered from a number of QFIs and Trainees, and subsequently de-identified. These were then replayed to QFIs who were asked to judge the proficiency of the recorded pilot(s).

Subjective data was collected through interviews with QFIs and program stakeholders. This information provided important context and user feedback.

Results:

H1.
Questionnaire data provided mixed support for this (improved awareness when CTS was functioning as intended, however effects were negated when it was not). Interview data provided support for this.

H2.
Unable to be addressed using objective data due to data losses. Subjective data (interviews) provided some support for this hypothesis.

H3.
Unable to be properly addressed as CTS was not used during debriefing. Subjective data (interviews) however indicate that Instructors expect this tool to have significant potential for debriefing.

H4.
Objective data provided mixed support for this (eye movement data indicated differences between more experienced versus less experienced pilots, however, instructors' subjective data did not). Interview data provided support for this.

Conclusions: Through Jericho Dawn 18-8 eye-tracking based training aids were shown to have high value potential in improving flight training outcomes, and in enabling instructors. However, without effective system integration and instructional workflow integration, the benefits of eye-tracking based training aids are unlikely to be realised.

New shelf stable food technology to enable future feeding systems with increased resilience and performance

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Background: Current ADF field ration systems rely on either fresh feeding from the set-up of field kitchens or the use of combat ration packs (CRP) when food preparation facilities are not available. However, fresh feeding from field kitchens requires substantial logistics support for maintaining the cold chain and associated services. Field kitchens require days to set up and have a large operational footprint. While CRPs are designed to provide enough nutrition for daily needs they are not formulated for long-term use. Selective consumption, combined with menu fatigue, can result in nutritional deficits for energy, protein, macro and micronutrients. This undernutrition rapidly causes cognitive and physical performance deficits and potential weakness in the immune response to microbiological challenges.

Aim: To develop shelf stable fresh-equivalent foods to improve in-field nutritional consumption, reduce or eliminate reliance on cold chains for group feeding, and enable the development of logistic systems that are more flexible, responsive and resilient.

Approach: The project is developing the use of the Microwave Assisted Thermal Sterilisation (MATS) for Defence applications. The MATS system uses 6-20 kW microwave energy inputs to rapidly heat the interior of sealed food packages to render them sterile in minutes minimising over processing that results when only conductive heat is applied in conventional retorts. A full pilot plant system at DSTG Scottsdale is used to validate the process and packaging conditions to make high quality Defence foods that can be formulated to be robust to degradative changes over 2 years at 30oC.

Progress: The MATS-B (pilot plant scale) is being used to optimise processing variables to achieve rapid uniformity in heating and to validate achieving sterility and high food quality. A range of single serve heat-and-eat meal types have been made from breakfast through to meat and vegetable main meal and dessert options. Research has developed a “model” potato starch-based gel that can be adjusted in dielectric properties to match specific foods and used to demonstrate heating patterns under different microwave conditions and for different food types. The system has been modelled using microwave and thermal heating software to produce a digital twin to simulate food passing through the MATS system. The digital model was validated by comparison with the model food outcomes for proof of concept, in optimising the processing variables by computer simulation in advance of practical trials. Electronic tongue and electronic nose technologies have also been applied to measure how changes in processing and storage variables change the taste and flavour of the food without using sensory panels.

Future development: The research will be applied to the development of stable food solutions for Defence Services that can then be field tested by users and demand communicated to the food manufacturing industry to assist the development of sovereign commercial production of stable meals-ready-to eat and food ingredients ready-to-use in Australia.

Reference:

Hong YK, Stanley R, Tang J, Bui L, Ghandi A. Effect of Electric Field Distribution on the Heating Uniformity of a Model Ready-to-Eat Meal in Microwave-Assisted Thermal SterilizationUsing the FDTD Method. Foods. 2021 Feb 3;10(2):311.

Monitoring Recovery From Muscle Damage Caused By Training

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Background: Musculoskeletal Injury (MSKI) can result from intensive physical training and is reportedly the most significant cost to military health around the world (Newman et al. 2020). In 2018, 53% of the U.S. Army had sustained a new MSKI, and of these, 71% were considered preventable (Newman et al. 2020). One risk factor for MSKI is linked to the frequency and intensity of training sessions. Intense training can cause muscle microtrauma and an associated inflammatory response. Without sufficient recovery, further training sessions can exacerbate muscle trauma and cause serious muscle injury.

We have developed a fingerpick blood test to assess metabolic health and propose that the test can be used to monitor muscle recovery from training. The test measures the oxidation state of albumin, the most abundant protein in blood.

Aim: We hypothesize that albumin oxidation can be used to track muscle damage caused by intense exercise. To test this hypothesis, we tracked albumin oxidation after damaging eccentric exercise and compared it to non-damaging concentric exercise. To determine the extent of muscle damage and muscle recovery we measured muscle force production.

Method: Fourteen healthy male participants who had not engaged in strength training for the previous 6 months were randomly assigned eccentric or concentric exercise. Participants performed either 210 eccentric contractions of the knee flexor on a Biodex dynamometer or 40 minutes of concentric cycling at 70% VO_2 max. Participants in the eccentric group self-collected fingerpick blood each morning before breakfast and returned to the laboratory every 2 days (5 sessions total) for a further blood sample and assessment of muscle force. To measure muscle force production, a dynamometer was used to measure maximal voluntary contraction (MVC). Concentric participants collected fingerprick blood immediately post exercise and every 30 min thereafter (6 samples total). Participants returned to the laboratory for the next 3 days for a fingerpick sample and an MVC assessment.

Results: Following eccentric exercise albumin oxidation was elevated from day 2 to day 8 ($P=0.0001$). MVCdeclined immediately post exercise and remained diminished until day 6 ($P<0.0001$). MVC exhibited a negative correlation with albumin oxidation ($P=0.001$). Following concentric exercise, albumin oxidation was elevated after 180 min ($P=0.0024$) but was not significantly different 1 day after exercise. MVC was decreased immediately post exercise ($P=0.0202$) but had recovered by 1 day after exercise.

Conclusions: These data indicate that albumin oxidation can be used to distinguish muscle damaging exercise from non-damaging exercise. Furthermore, they indicate albumin oxidation may be useful as a biomarkerto track muscle recovery where exercise has caused muscle damage. Due to the simplicity of the technique, albumin oxidation testing has the potential to be used for routine measurement of muscle recovery after training or during deployment of ADF personnel.

References:

Newman, P. Witchalls J. Stannard, J & Williams, E. (2020). *Defence Human SciencesSymposium 2020*, 1, 37-37.

Using Past and Present Indicators of Human Workload to ExplainVariance in Human Performance

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Background: Understanding human performance is a fundamental aim of psychologists in general, but is of particular importance to those who operate in the Defence space. Poor human performance can literally lead to life-threatening situations. Cognitive workload has been assumed to influence performance by changing the cognitive resources available for tasks, i.e. resource competition. However, there is a lack of evidence for a direct relationship between changes in workload within an individual over time and changes in that individual's performance.

Aim: We aimed to demonstrate the first empirical evidence for a direct relationship between objectively-measured cognitive workloadand performance on a real-world relevant task (here, a visual tracking task). We further aimed to determine whether this relationship could be used to *predict* performance decrements – i.e. identify a relationship between workload at time *x*, and performance at time *x+1*. Finally, we aimed to establish the homogeneity of workload-to-performance decrements, i.e. how consistent are these impairments across individuals?

Method: We collected performance data using a Multiple Object Tracking task in which we measured workload objectively in real-time using a modified Detection Response Task. We estimated workload on each tracking trial (15s intervals) and obtained performance scores as the number of correctly identified targets. We subjected the performance scores to multi-level Bayesian logistic regressions to determine the relationship between workload during the performance period, and workload preceding that performance period, on tracking performance, allowing for heterogeneous individual coefficients and controlling for task difficulty.

Results: We found strong evidence that workload both during and preceding a tracking trial was predictive of performance, such that higher workload led to poorer performance. These negative workload-performance relationships were remarkably consistent across individuals. Importantly, we demonstrate that fluctuations in workload independent from the task demands accounted for significant performance variation.

Conclusions: The outcomes have significant implications for designing real-time adaptive systems to proactively mitigate human performance decrements, but also highlight the pervasive influence of cognitive workload more generally. Work systems should be designed to minimise cognitive workload, and active monitoring of workload should be a research priority area (e.g., identifying reliable, time-precise biophysical markers of workload).

Performance-Focused Cognitive Fitness Intervention for Athletes Affected by COVID-19

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Background: The core dimensions of cognitive fitness are emerging as a transdisciplinary expert consensus (Albertella et al., 2020) on Cognitive Fitness Framework (CF2; Aidman, 2020). They represent keydrivers of cognitive performance under pressure across many occupations, from first responders to sport, performing arts and the military. These drivers include primary cognitive capacities such as attention and inhibitory control. Similar to physical conditioning, cognitive fitness can be improvedwith deliberate practice (Zaichkowsky & Peterson, 2018). This report covers the development of a prototype cognitive fitness program for competitive athletes, focused on mental capacities and subtending skills for adjusting training rhythms and enhancing readiness for competition.

Method: Australian Psychological Society's College of Sport & Exercise Psychologists is developing a CF2- informed paradigm for the Mental Health - Performer Wellbeing - Performance Support operating environment. This practitioner-led project is developing a Cognitive Gym program for a smartphoneapp-enhanced implementation. Its key building blocks are training protocols (drills) connected by a periodised training plan. National-level training squads will be invited to participate in a three-week pilot evaluation. Their coaching staff will evaluate the program, in addition to gamified cognitive assessment of participants' training gains.

Results: For the "proof of concept" requirements of the project, several drills were combined into a single intervention. The current prototype contains a standard daily practice routine containing 10 drills representing Composure, Recovery, and Mission-Ready phases of the CF2 cycle complemented by Performance Mindset instruction added by the practitioners. Each drill involves systematic and disciplined execution of underpinning cognitive skills, such as concentration endurance and attentional flexibility that combine the CF2 Delphi expert consensus on attention as a key fitness factor, with practitioner wisdom of how to best deliver attentional training. The content combines evidence-based training protocols with instructional support by practitioners experienced in the delivery of such programs in high performance environments. The core instruction is delivered via theapp and backed by a companion website providing extensive background information and additional practice options. The core recommended three-week sequence of daily interaction with the app includes practice drills, instructional material, assessments and interactive communication systems tofacilitate engagement.

Discussion: Participant recruitment and data collection have been delayed due to COVID-19 restrictions, and willcommence as soon as it becomes possible. Evaluation of the pilot training program will focus on estimating the objective training gains and on subjective assessments by athletes and coaches. The findings will inform future development of the app, with expansion options discussed. The impact of this training program on a range of performance and wellbeing outcomes seems worth further investigation. Our practitioner-driven implementation of a CF2-informed Cognitive Gym training intervention is one of several lines of research and development effort aimed at validating the CF2 constructs, their measurement and implementation of their practical applications. The project is closely aligned with the CF2 Delphi study and the associated development of cognitive measurementtools. It holds considerable promise to radically change the ways in which competitive athletes and other performance-focused professionals prepare for their occupational challenges.

A Meta-analysis of Deployment-related Demands and Resources for EmotionalResilience, Cognitive Functioning and Job-performance in Military Personnel

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Background: Our understanding of the military deployment experience is limited to piecemeal meta-analyses investigating a narrow suite of deployment demands (e.g., potentially traumatic events) and outcomes (e.g., post-traumatic stress). We expand this knowledge base via a large scale synthesis of the breadth and relative associations of deployment demands and resources related to eight outcomes: post-traumatic stress, depression, anxiety, psychological distress, burnout, capacities for resilience,job performance and cognitive functioning.

Aim: The broad aims were to: (1) examine the breadth and relative associations of deployment demands and resources related to three constructs of operational significance, (2) identify potential gaps in military deployment research, (3) identify potentially common adaptive or maladaptive deployment-related conditions, (4) determine whether objective exposure to traumatic events during deployment were more or less strongly associated with outcomes in the context of other deployment- related demands, and (5) provide recommendations about how to reduce the deleterious effects of deployment environments and directions for future research.

Method: We conducted a broad search for primary studies across seven databases and the grey literature by searching Defence Government websites and placing an information request to the five- nation technical collaboration panel. A total of 24,446 citations were identified. After removing duplicates and studies that did not meet inclusion criteria a total of 283 studies were retained with a sample of 3,058,436 (M = 10,845.51). Twenty-five categories of deployment demands and 17 categories of resources across the studies were identified.

Results: The results suggest that low-intensity, frequent non-traumatic stressors may play a pivotal role in the processes of individual vulnerability to emotional distress, capacities for resilience, and contribute to cognitive and performance outcomes. Affective experiences (i.e., guilt and shame, anger) and negative appraisal of deployment (e.g., powerlessness) were dominantly associated with at least two indicators of emotional resilience. There was also consistency in the resources dominantly associated with positive outcomes, in particular, adequate sleep, a positive motivational orientation (i.e., organizational commitment), and the use of various coping strategies. Studies of job performance in the context of deployment job-demands and resources were few. Deployment demands with the greatest association with job performance were the effects of deployment on family life/functioning, other negative appraisals of deployment (e.g., meaninglessness of deployment), and concerns or worries about deployment and its broader effects (e.g., on career outcomes). In terms of

cognitive function, the limited evidence suggests strong negative associations with physical demands (e.g., heat stress) and negative affective states such as tension, stress, and anger.

Conclusions: To date, there has been a strong emphasis on the measure of exposure to objective events (e.g., combat exposure) and deployment-related demands more broadly. However, the emotional and cognitive experiences of both traumatic and non-traumatic events may be more influential in predicting personnel emotional resilience than the objective events. The trends observed also suggest that resources make an important contribution to peri or post-deployment outcomes and yet they are not well researched. Further, we provide evidence of the deployment correlates that may be the most detrimental to emotional resilience, job performance and cognitive functioning.

The Role of Emotional Awareness: A Qualitative Investigation into the Resilience of Emergency Services Personnel

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Emergency services personnel are frequently confronted with stressors, ranging from occupational pressures to life-threatening situations. They are at risk of emotional ill-heath because their daily routine involves unpredictable traumatic stressors. Recent research suggests emotional awareness maybe a key variable promoting resilience. To further investigate these potential links, this study exploredthe experiences of emergency services personnel and links between emotional awareness and resilience. We adopted thematic analysis of eleven in-depth interviews with emergency services personnel. Participants identified resilience as crucial when coping with stressors, however, they defined resilience as remaining unemotional and unaffected by these stressors. These potentially unhealthy beliefs may impact their ability to remain resilient, demonstrating low emotional awareness. Participants defined emotional awareness as understanding emotions, triggers and reactions, and recognised associated benefits on communication, coping, resilience and burnout. Nonetheless, most participants did not engage in practices to improve their emotional awareness. Although most participants were aware of the benefits, there remained barriers such as beliefs or lack of skills that interfered with participants' ability to cultivate emotional awareness to promote resilience. With this in mind, some participant narratives described profound improvements in resilience and more adaptive coping, in response to trauma, through the cultivation of emotional awareness through mindfulness and reflective practices. Thus, developing emotional awareness may help emergency services personnel process difficult experiences and enhance their resilience, promoting well-being and career longevity. Training on resilience and emotional awareness would be beneficial at the individual, organisational and economic level.

Keywords: emergency services, mental health, burnout, awareness, resilience

Risk, Resilience and Recovery: Maximising Human Health and Performance in Extreme Environments through Interdisciplinary Translational Research Paradigms

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Background: Enhancing staff wellbeing and resilience to stressors (both routine and unanticipated) isa primary focus for many organisations, with multiple benefits for both the individual and the organisation. Within Defence contexts, these benefits further extend to the community through enhanced performance within the work role. Unsurprisingly, organisations and researchers are increasingly focused on identifying and addressing factors that enhance human health and performancewithin both individual and organisational contexts.

There are a range of complex and interrelated factors identified as influencing human health, resilience,and performance that vary depending upon the context in which one is placed. To date, researchers within these populations tend to focus on only one or a small set of related factors when investigating methods to enhance health and organisational outcomes. Whilst valuable, without an integratedframework that considers the complex interplays between these factors, results may not translate to operational contexts with the intended impacts or outcomes. Further, this fragmented approach does not as readily facilitate proactive, forward-thinking research agendas that drive innovation in maximising human health, resilience and performance.

Aim: This presentation will provide an overview of the interdisciplinary, whole of system approaches adopted by the University of Tasmania to provide end-to-end interventions to maximise human healthand performance in environments typical of those encountered within Defence contexts. Spanning proactive prevention through targeted intervention programs, we detail an innovative translational research agenda addressing the multifaceted components of individual, interpersonal, organisational and societal factors that influence human health and performance. These components include, but are not limited to, the identified key operational needs of DHSS: cognitive enhancement and augmentation;risk assessment and decision making; food and nutrition; assistive technologies; physiology; ethics; human systems analysis; human systems integration; organisational effectiveness; health and safety; organisational culture; and personnel selection and retention.

Conclusions: By adopting an interdisciplinary paradigm, the University of Tasmanian has enabled a forward-thinking research agenda offering end-to-end interventions addressing the complex interplay of individual, interpersonal, organisational and societal factors that influence performance. In doing so,they are able to collaboratively work with industry partners to deliver customised strategies to maximisehuman health, resilience and performance. The University of Tasmania's innovative interdisciplinary approach to translational research provides an opportunity to maximise the human health and performance needs of both contemporary and future defence operations.

The physiological effects of weapon handling during load carriage

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Background: Few investigations have explored the effect of weapon handling on load-carriage performance, despite it being essential during training and operations (Knapik et al., 2004; Seay, 2015). Weapon handling restricts arm swing and shifts a portion of the load anteriorly during walking (Birrell& Haslam, 2008). Further, restricted arm swing increases energy expenditure by ~5-17% during unloaded walking between 4 and 7 km/h (Umberger, 2008; Yizar et al., 2009). Past research exploringthe physiological effects of restricted arm swing in a military context is limited to jerry can/stretcher carriage (>30kg) in the hands (Datta & Ramanathan, 1971; Knapik et al., 2000). However, limited research has examined the effects of restricted arm swing related to weapon handling (Seay, 2015).

Aim: Investigate the effect of weapon handling on cardiorespiratory and perceptual responses during load carriage.

Method: Twenty Australian Army soldiers (14 male, 6 female) completed four twelve-minute bouts of treadmill walking (3.5, 5.5, 6.5 km/h and self-selected [5.0±0.2 km/h]) while carrying 23 kg of load ineither a weighted vest (free arm swing) or with the mass split between the vest and a replica F88 Austeyr(3.2 kg; restricted arm swing). Expired gas analysis was undertaken with a portable metabolic system,while heart rate and ratings of perceived exertion (Borg rating of perceived exertion scale [RPE]; omnibus-resistance exercise scale [OMNI]) were also collected. Cardiorespiratory data (expired gases,heart rate) were averaged for every three minutes of steady-state walking, while perceived exertion datawere collected at the end of each trial. A mixed model clustered by participant was used to assess the interaction and main effects of walking speed and weapon handling with *post-hoc* tests performed where significant effects were present. Statistical significance was set as $p<0.05$. Data are presented asmean difference ± standard error.

Results: There was a significant interaction for heart rate ($p=0.038$), with weapon handling increasingheart rate by 7±2 bpm ($p=0.016$) above free arm swing at 6.5 km/h. There were no other interactions nor main effects of weapon handling for any other variable. All variables increased with increasing speed ($p<0.001$). RPE increased with greater walking speeds, except between self-selected and 5.5 km/h($p=0.067$), while OMNI scale ratings increased between 3.5 and 6.5 km/h ($p<0.001$), and self-selectedand 6.5 km/h ($p=0.005$).

Conclusions: While restricted arm swing during weapon handling did not affect respiratory orperceptual variables during load carriage, heart rate was greater when walking at 6.5 km/h compared with free arm swing. This suggests that military operations that require a faster walking speed and weapon handling may not be perceived to be of greater physiological burden, despite elevatedcardiovascular stress. The observed increase in heart rate relative to VO_2 is a likely result of the isometric muscle contractions and greater upper-body muscle activation required to hold and stabilise the weapon (Gálvez et al., 2000). Subsequently, the increased heart rate immediately following load carriage at faster speeds (e.g. movement to contact) may have implications for subsequent task performance such as marksmanship (Tenan et al., 2017).

References:

Birrell, S. A., & Haslam, R. A. (2008). The influence of rifle carriage on the kinetics of human gait.
Ergonomics, 51(6), 816–826.

Datta, S. R., & Ramanathan, N. L. (1971). Ergonomic comparison of seven modes of carrying loads onthe horizontal plane. Ergonomics, 14(2), 269–278.

Gálvez, J. M., Alonso, J. P., Sangrador, L. A., & Navarro, G. (2000). Effect of muscle mass and intensityof isometric contraction on heart rate. *Journal of Applied Physiology*, 88(*2*), 487–492.

Knapik, J. J., Harper, W., Crowell, H. P., Leiter, K., & Mull, B. (2000). Standard and alternative methods of stretcher carriage: performance, human factors, and cardiorespiratory responses. *Ergonomics*, 43(*5*), 639–652.

Knapik, J. J., Reynolds, K. L., & Harman, E. (2004). Soldier load carriage: historical, physiological, biomechanical, and medical aspects. *Military Medicine*, 169(*1*), 45–56.

Seay, J. F. (2015). Biomechanics of load carriage. *The Mechanobiology and Mechanophysiology of Military-related Injuries*. Springer.

Tenan, M. S., La Fiandra, M. E., & Ortega, S. V. (2017). The effect of soldier marching, rucksack load,and heart rate on marksmanship. *Human Factors*, 59(*2*), 259–267.

Umberger, B. R. (2008). Effects of suppressing arm swing on kinematics, kinetics, and energetics of human walking. *Journal of Biomechanics*, 41(*11*), 2575–2580.

Yizhar, Z., Boulos, S., Inbar, O., & Carmeli, E. (2009). The effect of restricted arm swing on energy expenditure in healthy men. *International Journal of Rehabilitation Research*, 32(*2*), 115-123.

Soldier neuromuscular fatigue in response to varying simulated occupational field tasks: utility of the counter movement jump and isometric mid-thigh pull.

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Background: Soldiers are subjected to accumulating workload during role-specific tasks and physical training sessions which presents as perceptual and physiological fatigue. In preparing for periods of high tempo, the management of training fatigue first relies on identifying valid markers. Perturbationsin maximal voluntary power and strength have been demonstrated to be relevant to neuromuscular fatigue in athletes performing activities such as running and jumping (Gathercole et al. 2015). Notwithstanding, the applicability for identification of neuromuscular fatigue in the elite soldier, using the CMJ and IMTP, is less understood as they pertain to recruitment activities. This training environment is uniquely characterised by both integrated physical training sessions and simulated occupational tasks such as protracted military activities in the field.

Aim: To quantify the neuromuscular fatigue of soldiers taking part in simulated occupational tasks during an elite soldier preparation course, by use of the CMJ and IMTP.

Method: Eighty-six (n=86) participants completed (i) a high intensity 6 h Physical Entrance Test (PET), (ii) a moderate intensity 36 h operational task (36h) and (iii) a low tempo 6 h operational task (6h) in that order. These tasks were separated by >14 days of physical training. Before and after each task the participants completed a validated self-perceived rating of fatigue (ROF) scale (Micklewright, et al. 2017), CMJ (Gathercole, et al. 2015) and IMTP (Maffiuletti, et al. 2016) using Force Decks (VALD Performance, Australia). Data was sampled at 1000 Hz and all performance indices were saved to the VALD ForceDecks Performance Software™ before being exported for analysis. Performance indices collected during the CMJ and IMTP were analysed within condition(pre and post, mean [SD]) using effect sizes (ES).

Results: Self-reported ROF, before each task, progressively increased throughout the course (pre- PET: 1.55[1.20]; pre-36h: 2.50[1.37]; pre-6h 3.34[1.68] /10; $p<0.05$). Relative to before each task, post completion ROF was observed to significantly increase after both PET (pre: 1.55[1.20]; post: 6.76[1.62]; $p<0.001$) and 36h task (pre: 2.50[1.37]; post: 7.31[1.26]; $p<0.001$), however no significantincrease was evident in the 6h task (pre: 3.34[1.68]; post: 3.89[1.73]; $p=0.143$). The greatest reductionin CMJ concentric time to peak force (CTPF) was observed following the PET (strong ES: 1.03) and

36h task (moderate ES: 0.74). Likewise, the greatest reduction in IMTP peak vertical force (PVF) and rate of force development (RFD) were observed following the PET (RFD: strong ES 1.14; PVF: moderate ES 0.92) and 36h task (RFD: moderate ES 0.48; PVF: moderate ES 0.82). In contrast, no perturbations were observed in CTPF, PVF or RFD following the completion of the 6h task (ES all <0.18).

Conclusions: This study provides evidence of accumulated perceptual and neuromuscular fatigue occurring during an elite soldier preparation course. Importantly, a number of key kinetic temporal indices were able to detect occupationally specific neuromuscular fatigue states according to the task demands. The regular inclusion of CMJ and IMTP testing will allow physical training instructors to understand the neuromuscular fatigue states of personnel and the goal is to implement these kinematictemporal indices as part of a prescribed physical training program.

References:

Gathercole, R., B. Sporer, T. Stellingwerff and G. Sleivert (2015) Alternative countermovement-jumpanalysis to quantify acute neuromuscular fatigue. *International Journal of Sports Physiology and Performance*, 10(1), 84-92.

Maffiuletti, N. A., P. Aagaard, A. J. Blazevich, J. Folland, N. Tillin and J. Duchateau (2016) Rate offorce development: physiological and methodological considerations. *European Journal of Applied Physiology*, 116(6), 1091-1116.

Micklewright, D, St Clair Gibson, A., Gladwell, V., and Al Salman, A. (2017) Development and Validity of the Rating-of-Fatigue Scale. *Sports Medicine*, 47(11), 2375-2393.

Gut microbiota and its neuroactive potential corelated to cognitive functions in the healthy elderly adults

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Background: Aging is associated with changes in a range of biological processes, including impairment in cognitive functions and gut microbiome diversity. The relationship between the gut microbiome and brain health are one of the most captivating topics in gut microbiome research. Bidirectional microbiome–gut–brain communication has extensively been explored in animal models,while human research is lagging behind. Large-scale epidemiological studies could provide theunderstanding and evidence for microbiome–gut–brain interaction in human.

Objectives: The presentstudy evaluated the relationship between cognition and microbiome in healthy elderly participants. Further, neuroactive potential of gut microbiota by functionals characterisation was explored tounderstand the mechanisms by which gut microbiome influences the cognition.

Method: The present study included 69 healthy men (34) and women (35) participants aged between 60-75 years old. The cognitive assessment included the Cognitive Drug Research computerised assessment battery (CDR) for five cognitive factors, 'Quality of episodic secondary memory', 'Quality of working memory', 'Continuity of attention, 'Speed of memory' and 'Power of concentration'. The gut microbiome was assessed by the 16S-rRNA sequencing method and functional prediction of the microbiome was assessed using Phylogenetic Investigation of Communities by Reconstruction of Unobserved States (PICRUST2). Functional predictions were grouped into the gut-brain specific functions based on Omixer-rpmR workflow.

Results: Multiple linear regression showed that bacterial families *Carnobacteriaceae* accounted for a 9% variance in predicting the Quality of episodic secondary memory (p=0.006). *Alcaligenaceae* and *Clostridiaceae* accounted for 15% variance in predicting Working Memory (p=0.002); *Bacteroidaceae, Barnesiellaceae, Rikenellaceae* and*Gemellaceae* together explained 11% of the variance in Power of concentration (p=0.024). Our resultsreported propionate production pathway was negatively associated with continuity of attention (r= - 0.311, p-value= 0.011). Power of concentration was negatively related with tyrosine production pathway (r=0.274, p-value=0.024) and phenylalanine degradation (r=0.274, p-value=0.024). Negative associations were revealed between gut brain modules tyrosine production I (r=-0.246, p- value= 0.045), phenylalanine degradation (r=-0.246, p-value=0.045) and working memory.

Discussion: The findings of the study provide preliminary evidence of associations between specific bacteria at the family level and specific domains of cognitive functions. We identified microbial synthesis potential of neuroactive metabolites through analysis of faecal metagenomes. Microbial synthesis potential of metabolites involved in neurotransmitter production correlated with cognitive performance and indicated potential role of microbial short chain fatty acid production. Our results provide evidence for neuroactive potential of gut microbiome in the brain functions. These results would guide future mechanistic studies to examine the causes of these associations.

Mechanisms of vigilance loss: Sensitivity decrements less robust than bias shifts and attentional lapses

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Background: When human operators are tasked with detecting rare signals among noise, as when monitoring radar displays for threats or automated warning systems for failure, they usually experience a decline in detections over time. This phenomenon, termed the *vigilance decrement,* is usually attributed to conservative shifts in observers' willingness to response (i.e., response bias) and losses in their ability to distinguish signal from noise (i.e., sensitivity) in high event rate, memory- loading tasks (Parasuraman & Davies, 1977). Recent work, however, suggests that bias shifts can masquerade as losses of sensitivity when false alarms are near-zero (Thomson et al., 2016) and produce spurious changes in the sensitivity measure *A'* (McCarley et al., in press). These issues prompt reconsideration of the causes underlying vigilance decrements.

Aim: Current theories invoke three potential explanations of the vigilance decrement, but binary signal detection data are unsuitable for distinguishing between them. Employing a novel method of data analysis, we conducted four experiments examining the extent to which vigilance decrements reflect changes in bias, sensitivity, and attentional lapses.

Method: Across four experiments, 477 participants completed a visual go/no-go signal detection task, judging whether the separation between two probes exceeded a criterion value. Separation between the probes varied across trials and data were fit with logistic psychometric curves. Experiments 1 (N =99; McCarley & Yamani, in press) and 2 (N = 58) were conducted in the lab using a 20-minute task. Experiments 3 (N = 123) and 4 (N = 197) were conducted online using a shortened 12-minute task. For each experiment, parameters representing sensitivity, response bias, and attentional lapse ratewere compared across the first and last four minutes of the vigils in a hierarchical Bayesian model.

Results: Experiment 1 gave decisive evidence that the decrement was driven by conservative shifts in response bias, decreased sensitivity, and increased attentional lapses. Experiment 2, which was halted early due to restrictions on in-person data collection, was less clear. Posterior distributions shifted in the direction of losses driven by changes in response bias, sensitivity, and lapse rate, but results were inconclusive. Experiments 3 and 4 replicated the conservative bias shift and increased attentional lapses observed in the first experiment but did not find evidence that sensitivity declined.

Conclusions: Although Experiment 2 did not provide clear evidence of a vigilance decrement (likely due to reduced statistical power), the completed experiments showed that the decrement was drivenby all three proposed mechanisms of vigilance loss in the lab-based task, but only by attentional lapses and conservative shifts in response bias in the online task. This discrepancy might be due to differences in task length or attention allocation in the lab versus uncontrolled settings. In any case, sensitivity losses appear less robust than other explanations of the vigilance decrement, which is at odds with theories that attribute vigilance decrements primarily to changes in sensitivity. Being ableto distinguish between these three forms of vigilance loss, and in turn, understand why vigilance declines, is necessary to effectively mitigate the decrement in applied settings.

References:

McCarley, J. S., & Yamani, Y. (in press). Psychometric curves reveal three mechanisms of vigilance decrement. *Psychological Science*.

McCarley, J. S., Yamani, Y. & Gyles, S. P. (2021, October). Comparing measures of sensitivity for vigilance tasks: Bayesian-estimated and loglinear-corrected measures outperform $\boldsymbol{A'}$. In *Proceedings of Human Factors and Ergonomics Society Annual Meeting.*

Parasuraman, R., & Davies, D. R. (1977). *A Taxonomic Analysis of Vigilance Performance. Vigilance*, 559–574. https://doi.org/10.1007/978-1-4684-2529-1_26

Thomson, D. R., Besner, D., & Smilek, D. (2016). A critical examination of the evidence for sensitivity loss in modern vigilance tasks. Psychological Review, 123(1), 70. https://doi.org/10.1037/rev0000021

The effect of weapon handling and walking speed on local dynamic stability of gait

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Background: Weapon handling is required during military training and operations, however, carrying an asymmetrical load that restricts arms swing may lead to compensatory actions that affect walking stability (Drain et al, 2012, Bruijn et al, 2010). As speed affects walking mechanics, the effect of weapon handling on stability may be amplified, eliciting trunk or pelvis compensatory actions. Since maintaining stability is one of the main aims during gait, increasing walking speed during weapon handling may cause gait to become less stable and potentially increase musculoskeletal injury risk.

Aim: To determine the effects of weapon handling and walking speed during load carriage on gait stability at the sacrum and trunk. We hypothesised that instability measured at both locations would be greater when carrying a weapon and with faster walking speeds.

Method: Fourteen Australian Army soldiers with no history of recent musculoskeletal injuries were recruited (3f/11m, height 178 ± 9 cm, mass 84 ± 14 kg, age 25 ± 5 years). Participants walked on a treadmill at a self-selected speed (SS; 5.0 ± 0.2 km/h), 3.5 km/h, 5.5 km/h and 6.5 km/h for 12 minutes while carrying a 23 kg evenly distributed weighted vest and with and without a 3.2 kg replica F88-Austeyr. The weapon was carried in a two-handed position across the body. A 10-minute rest was given between trials. Stability was assessed with the short-term local divergence exponent (Lyapunov; LDE) using 3D accelerations recorded with a 4-APDM (Portland, USA) IMU system (128 Hz) placed at the feet, sacrum, and sternum (manubrium). Data from the foot sensors were usedto determine heel contacts for 200 consecutive strides. To calculate the LDE (LDE_{sacrum} and LDE_{trunk}),data were first normalised to 100 data points x 200 strides. The 9D state space was constructed using3 x 3D delayed copies (10 samples delay) using Rosenstein's algorithm (Bruijn et. al., 2013) anddivergence rate was calculated in the 0-0.5 stride interval. In brief, the LDE measures the ability of a person to deal with step-to-step perturbations, where higher LDE values indicate lower stability. All calculations were performed in Matlab 2020b (Natick, USA). IBM-SPSS 27 was used to conduct two-way repeated measures analyses of variance (4 speeds x 2 weapon on/off) on LDE_{sacrum} and LDE_{trunk}.

Results: No interactions were found between speed and weapon handling. A significant reduction in LDE_{trunk} ($p<.01$) but not LDE_{sacrum} was found when handling the weapon. A significant effect of speed($p<.01$) was found for both, LDE_{sacrum} and LDE_{trunk}.. Pairwise comparisons showed LDE_{trunk} at 3.5 km/h was significantly higher than the three faster conditions, and LDE_{trunk} was significantly higher ($p<.01$) at SS (~5.0 km/h) compared with 6.5 km/h.

Conclusions: Contrary to our hypothesis, weapon carriage increased gait stability when measured at the trunk. Furthermore, decreased speed increased LDE (less stable) at the trunk and sacrum. These results indicate that carrying a weapon tightens the control of the trunk during walking with load and that slower walking speeds (e.g., 3.5 km/h) may be more stability-challenging than walking close to, or above, self-selected speed.

References:

Drain, J. Orr, R. Attwells, R. Billing, D. (2012) Load Carriage Capacity of the Dismounted Combatant - A Commanders' Guide. DSTO-TR-2765, 1–69.

Bruijn S., Meijer O., Beek P. & van Dieën J. (2013), Assessing the stability of human locomotion: a review of current measures. J. Royal Society Interface 10:20120999.

Bruijn S., Meijer O., Beek P. & van Dieën J. (2010), The effects of arm swing on human gait stability. The Journal of Experimental Biology 213, 3945-3952

Physical and Physiological Load Monitoring in Military Settings —Opportunities and Pitfalls

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Load monitoring in Defence: With ongoing developments in wearable technology, quantifying physical/physiological demands (‘*load monitoring’*) is a growing area of Defence research. Much of this interest has likely stemmed from a proliferation of load monitoring publications in sport (Bourdon et al., 2017). Several studies have quantified aspects of the physical demands of military training (e.g., observation, accelerometry, and global positioning systems), as well as facets of associated physiological responses (e.g., heart-rate, subjective self-reports, and biochemical measures) (Michael et al., 2021). Mostpublished data have been collected during basic military training (BMT). For example, recruits from severalcountries perform large volumes of physical activity during BMT (e.g., averaging 13,000-17,000 steps or 11-14 km per day). However, ~75-85% of BMT consists of sedentary or light intensity (e.g., <3 estimatedMET), with <5% of activity classified as vigorous (>6 estimated MET). Similarly, recruits typically averageonly ~30 min per day above 60% heart-rate reserve. These averages are often reported as weekly summariesand are associated with substantial day-to-day and inter-individual variation (Michael et al., 2021).

Opportunities and pitfalls: Wearable devices provide many opportunities for Defence human performance science. For example, quantifying occupational (especially operational) demands can inform a needs analysis of physical/physiological requirements and thus facilitate evidence-based assessment/selection procedures and training objectives. However, there are also noteworthy pitfalls surrounding load monitoring. Without a clear scientific/practical objective and process for analysis/interpretation/decision, load data are of limited value. Exaggerated marketing claims regarding device validity and efficacy are a concern (Sperlich & Holmberg, 2017). There is an alarming level of advocacy surrounding the use of load monitoring to improve management (e.g., training prescription), for example, by purportedly increasing performance and/or reducing injury risk (Michael et al., 2021). Such claims are often not accompanied by testable models for how load data should be used in a feedback- decision-action loop to modify prescription/management to improve outcomes. The lack of sound causal frameworks in load-outcome models is also problematic when interpreting data (Impellizzeri et al., 2020).When tested in sport, load-outcome models have demonstrated poor predictive performance (Fanchini et al., 2018; Borresen & Lambert, 2009). If making predictions from new data, the base-rate prevalence (Bayesian prior) must not be neglected. For example, a seemingly well-performing screening test (e.g., 0.9/0.9 sensitivity/specificity) will result in 68% of positives being false positives (false discovery rate, FDR) if the underlying prevalence is 5%, and a 92% FDR for an underlying prevalence of 1%.

Future directions: The scarcity of published data reflecting operational demands represents an importantarea for future research to better inform the requirements of assessment/selection and training. Scientists should consider and justify the biological construct validity when interpreting load measures. If load measures are used for outcome prediction, establishing the predictive performance with Bayesian considerations of base-rate probabilities is essential. If load measures are used in a feedback-decision-action

loop to purportedly improve prescription/management, it should be demonstrated that modifying prescription based on these measures leads to superior outcomes, compared to operating without this feedback but otherwise according to established best practice.

References:

Bourdon, P.C., Cardinale, M., Murray, A., Gastin, P., Kellman, M., Varley, M.C., Gabbett, T.J., Coutts, A.J., Burgess, D.J., Gregson, W., and N.T. Cable (2017). Monitoring Athlete Training Loads: Consensus Statement. *International Journal of Sports Physiology and Performance*, 12(Suppl 2), S2161-S2170.

Michael, S.W., Siddall, A.G., O'Leary, T.J., Groeller, H., Sampson, J.A., Blacker, S.D., and J.R.Drain (2021). Monitoring Work and Training Load in Military Settings — What's in the Toolbox? *European Journal of Sport Science,* in press.

Sperlich, B., and H.C. Holmberg (2017). Wearable, yes, but able…?: it is time for evidence-basedmarketing claims! *British Journal of Sports Medicine*, 51(16), 1240.

Fanchini, M., Rampinini, E., Riggio, M., Coutts, A.J., Pecci, C., and A. McCall (2018). Despite association, the acute:chronic work load ratio does not predict non-contact injury in elite footballers. *Science and Medicine in Football*, 2(2), 108-114.

Borresen, J. and M.I. Lambert (2009) The quantification of training load, the training response and the effect on performance. *Sports Medicine*, 39(9), 779-795.

Impellizzeri, F.M., McCall, A., Ward, P., Bornn, L., and A.J. Coutts (2020). Training Load and Its Role in Injury Prevention, Part 2: Conceptual and Methodologic Pitfalls, *Journal of AthleticTraining*, 55(9),793-901.

The most discriminant components of force platform data for gait based person re-identification

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Background: Based on the observation that each gait cycle contains identifiable features, walking gait has been proposed as a means for person re-identification (re-ID) in authentication and surveillance scenarios (Cutting & Kozlowski, 1977; Nixon et al., 1996). Over the last two decades, the strengths and limitations of video-based re-ID systems have been well established, though the utility of force platform based re-ID systems remains largely unexplored (Connor & Ross, 2018).

Aim: Our first aim was to rank individual components of force platform data in terms of their effectiveness for the re-ID task using a novel deep neural network (*KineticNet*). Next, we wished to determine if using multiple components together is more effective than using the most discriminant component on its own.

Method: 118 healthy participants completed a repeated measures experiment that was conducted over two sessions with 3-14 days between each session. Participants walked the length of the laboratory (~10m) five times at preferred walking speed while wearing their own clothing and footwear (though footwear had to be consistent between sessions). At the same time, bilateral ground reaction forces
(Fx, Fy, Fz), moments (Mx, My, Mz), and center of pressure coordinates (Cx, Cy) were measured using two force platforms in the center of the laboratory. Of the 8-10 samples per participant, 2-3 per session were reserved for network training, leaving 1 per session for network validation and 1 per session for network testing. In phase 1, each individual component was used as the input to *KineticNet* to determine its effect on inter-session re-ID accuracy. In phase 2, top ranked components from phase 1 were combined at the input level (where the number of components included increased in a stepwise manner) to determine the effect of input level fusion on inter-session re-ID accuracy. Specifically, differences in test accuracy were compared using the independent samples t-test (α=0.01).

Results: The top three components were Fz (92.71±1.90%), Fy (85.00±3.52%), and Cy (70.85±3.68%), and the differences between each of these were significant ($p=6.29\times10^{-4}$ and $p=3.75\times10^{-6}$, respectively). Combining Fz, Fy, and Cy at the input level led to the highest accuracy overall at 96.02±1.26%, though the improvement over using Fz alone was non-significant ($p=1.36\times10^{-2}$).

Conclusions: The maximum accuracy obtained in this study forms the new benchmark for inter-session re-ID using force platforms. Also, this is the first work to show that Fz, Fy, and Cy are the most discriminant components of force platform data. These findings should accelerate the development of force platform based person re-ID systems by allowing engineers to focus on the most pertinent information.

References:

Cutting, J. E., & Kozlowski, L. T. (1977). Recognizing friends by their walk: Gait perception without familiarity cues. *Bulletin of the psychonomic society*, 9(5), 353-356.

Nixon, M. S., Carter, J. N., Cunado, D., Huang, P. S., & Stevenage, S. V. (1996). Automatic gait recognition. *Biometrics* (pp. 231-249). Springer, Boston, MA.

Connor, P., & Ross, A. (2018). Biometric recognition by gait: A survey of modalities and features. *Computer Vision and Image Understanding*, 167, 1-27.

Predicting real-time listener engagement from electrical brain activity: a proof-of-concept study

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Background: Understanding user-system engagement is essential in a world where the use of technology in all aspects of life is continuously increasing. Particularly in complex operational environments, human users rely heavily on technology and artificial intelligence (AI) to distil vast amounts of information into key insights for rapid decision making. To ensure successful operational outcomes under such circumstances, system input must be continually calibrated to the current needs of the user. However,it is highly challenging to gauge a user's engagement with an AI system and their level of comprehension in real time. In this proof-of-concept study, we examine the feasibility of using fluctuations in electrical brain activity as real-time estimates of listener engagement when exposed tonatural language input.

Aim: This work in progress examines a new approach to analysing real-time brain responses to naturalisticlanguage stimuli based on electroencephalographic (EEG) data. If successful, this approach could provide a real-time measure of user engagement and depth of comprehension, which could be used toprovide online feedback to AI systems during human-system teaming.

Method: Participants (currently n=14) listened to short narrations (mean word count: 456) and were tested on their level of comprehension after each one, whilst their EEG was recorded. Narrations were taken from three different genres to vary the level of comprehension complexity: fiction, non-fiction (newspaper reports) and popular science. In addition to genre, number of sentences and average sentence length, we examined two novel, sentence-based predictors of depth of comprehension: average surprisal, the unexpectedness of a word given its preceding context, and average N400 amplitude, a time-locked neurophysiological measure of how easily a word is understood given its context. Although both factors are known to be related to text comprehension, the uniqueness of the neurophysiological predictor (N400) to each individual allowed it to be utilised to account forindividual-level variability in language processing. Both predictors were analysed by averaging at the sentence level – a novel analysis approach– to decrease the level of noise in the signal. This is crucial for obtaining an interpretable signal in real time.

Results: Preliminary results with the current sample of participants suggest that average sentence-level N400 amplitude predicts the level of narrative comprehension. Lower N400 amplitudes were associated with better comprehension, though the strength of this relationship varied depending on story length and mean sentence length. No comparable effects were found for surprisal, thus indicating that a calibration to the individual listener via their neurophysiological activity may be crucial to predicting comprehension.

Conclusions: These preliminary findings suggest that our novel neurophysiological predictor (average N400 amplitude per sentence) is a promising potential measure for gauging a listener's depth of comprehension while they are listening to natural language input. In the context of user-system engagement, this methodological approach could be applied to measure effectiveness of communication by the system in real time, thereby allowing for appropriate communication adjustments if needed. At the conference, we will elaborate on these initial results by presenting a full proof-of-concept study with a larger sample size (intended n=20).

Early detection of high risk trials during manual handling tasks using machine learning models

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Background: Manual handling tasks are amongst the leading cause of back injuries. Ergonomic risk assessment methods are critical to workplace health and safety, as they contribute to the identification, measurement, and mitigation of work-related risk factors (David 2005). The current developments in machine learning have opened the possibility of using heterogeneous biomechanical features (joint angles) to detect an incorrect lifting or a heavy load that leads to a high-risk trial.

Aim: This study aims to develop a Logistic Regression (LR) model that classifies high-risk trials at early stage of lifting.

Method: Twenty one Male and 11 Female participants (29.5 ± 5.6 years old, 1.76 ± 0.10 m, 75.2 ± 12.7 kg) performed randomised manual handling tasks of weights relative to each of their maximum lifting capacity. The task was to pick up a box from the ground and place it on a platform fixed at 1.4m height. There were a total of 41 high-risk trials and 593 successful lifting trials. A motion capture system (Vicon Motion Systems, Ltd., Oxford, UK) recorded full-body kinematic data. The spine model was divided into six segments so that the input features for the LR model were the five relative angles withinthe spine model, the angle between lowest segment of the spine and the pelvis, left and right hip angles,left and right knee angles, and left and right ankle angles in the sagittal plane. Data from the full liftingtrials were chopped into a region of interest: from the start of the lift, to when the box was raised to thesubject pelvis height. This time was approximately 1sec.
Border-line Synthetic Minority Oversampling Technique (SMOTE) was implemented to identify and oversample misclassified high-risk lifting trials on the decision boundary of a Support Vector Machines classifier (Nguyen, Cooper et al. 2011). The technique was also used to under sample the majority class - successful trials (Chawla, Bowyer et al. 2002). After the application of SMOTE, there were a combination of original and synthetic trials (395 successful and 237 high-risk). A regularised LR was developed and tuned to discriminate the high-risk lifting trials.

Results: Stratified sampling of 10 fold cross validation was carried out to evaluate the LR performancein discriminating high-risk trials. For each of the 10 folds the same percentage of high-risk trials was maintained and the average precision and recall (sensitivity) was 90% ±0.03% and 96% ± 0.05% respectively. The sensitivity indicates the LR was better at detecting high-risk trial when there was actually a high-risk trial. While the lower precision shows that the LR classifies 1 high-risk trial out of10 actually successful trials.

Conclusions: Results suggested considerable potential for using the LR to detect high-risk trials from the lower limb and spine segment angles. The ability to predict a high-risk trial at the early stage of lifting would facilitate the development of smart wearable devices that alert the user and in turn minimise the risk of an impending injury. The study is limited to original 41 high-risk trials.

References:

Chawla, N. V., K. W. Bowyer, L. O. Hall and W. P. Kegelmeyer (2002). "SMOTE: synthetic minority over-sampling technique." Journal of artificial intelligence research **16**: 321-357.

David, G. C. (2005). "Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders." Occupational medicine **55**(3): 190-199.

Nguyen, H. M., E. W. Cooper and K. Kamei (2011). "Borderline over-sampling for imbalanced data classification." International Journal of Knowledge Engineering and SoftData Paradigms **3**(1): 4-21.

Effect of exercise training programs on musculoskeletal physical fitness domains in military personnel: A systematic review and meta-analysis.

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Background: Physical training is important to prepare soldiers for the intense occupational demandsin the military. However, current physical training may not address all fitness domains crucial for optimising physical readiness and reducing musculoskeletal injury. The effects of non-standard military training on fitness domains has been inconsistently reported, which limits the design of the ideal training program for performance optimisation and injury prevention in the military.

Aim: To systematically review the effects of exercise training on various fitness domains (i.e. aerobic fitness, flexibility, muscular endurance, muscular power, muscular strength, occupational specific performance, balance and core strength) that contribute to occupational performance and musculoskeletal injury risk in military personnel.

Methods: An extensive literature search was conducted in January 2021 and was subsequently updated in July 2021. Included studies consisted of comparative groups of healthy military personnelperforming standard and non-standard military training with at least one assessment representative ofa fitness domain. Study appraisal was conducted using the PEDro scale. Quantitative (meta-analysis)was conducted via forest plots, standard mean difference (SMD, effect size) and inter-trial heterogeneity (I^2). Qualitative analysis was also conducted for a small number of studies.

Results: From a total of 6744 records, 33 studies were identified as eligible for inclusion in this review with a total of 11381 participants. Average study quality via PEDro score was good (5/10; range 3/10-7/10). Non-standard military training resulted in greater post-training values for muscular strength via repetition maximum testing (SMD=1.51; P<0.00001; I^2=91%), muscular power (SMD=1.26; P<0.00001; I^2=89%), and occupational specific performance (SMD=0.47; P=0.01; I^2=64%) compared to standard military training. There were no differences for aerobic fitness via timetrial (SMD=0.04; P=0.33; I^2=54%), flexibility (SMD=0.33; P=0.13; I^2=75%), muscular endurance (SMD=0.18; P=0.05; I^2=91%) and muscular strength via maximum voluntary contraction (SMD=0.19; P=0.12; I^2=65%) between training groups. The qualitative analysis identified that non- standard military training resulted in greater post-training values for balance and core strength and greater mean changes for muscular strength, muscular power, muscular endurance, aerobic fitness andflexibility, compared to standard military training.

Conclusions: The current systematic review identified that non-standard military training had a greater post-training effect on muscular power, muscular strength measured via repetition maximum, occupational specific performance, balance and core strength compared to standard military training. Overall, these findings suggest that non-standard military training may be beneficial in optimising occupational performance while potentially reducing musculoskeletal injury risk.

Towards “appreciation superiority”: A set of proxy measures

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Background: Appreciation is the military term for a “logical process of reasoning by which a commander considers all the circumstances affecting the military situation and arrives at a decision as to the course of action (COA) to be taken in order to accomplish their mission” [1]. The ability to planand develop COAs that are feasible, acceptable, suitable, sustainable and distinguishable (FASSD [2])to achieve mission goals is a fundamental requirement for military officers. Doctrinally**,** the aim of the military appreciation process is to develop a timely, flexible, tactically sound, fully integrated and synchronised plan that increases the likelihood of mission success with fewest casualties.
As part of the Bright Fox project, we have been studying the metacognitive strategies that Army officersuse to formulate COAs during military planning operations [3, 4, 5]. More recently, our efforts have focused on how we might assess whether a commander (and their staff) is maintaining superiority overthe adversary during the appreciation process. In doing so, we identified a need to go beyond existing constructs like ‘FASSD’ and try to identify what ‘appreciation superiority’ is and how to measure it.

Aim: To identify an initial set of measures of appreciation superiority in military planning operations.

Method: A workshop was conducted with a senior Army officer with significant experience in military tactics and planning to explore the concept of appreciation superiority and its measurement.

Results: Appreciation superiority was conceptualised as a functional construct: to achieve appreciation superiority a commander must be able to continually form FASSD COAs where possible, regardless of the mission assigned and regardless of environmental factors or actions by the opposing force. By definition, an assessment of appreciation superiority can only be made post-mission; pre-outcome measures are only proxies. The following indicators and proxy measures were identified.
Speed [1]: the commander that can generate more FASSD COAs in a given time period is more likely to achieve superiority [Metric: number of FASSD COA generated per unit time].
Simplicity [2]: the commander who can produce FASSD COAs with the least number of parts is more likely to achieve superiority. [Metric: number of parts required to execute COA].
Adaptive capacity [3]: the commander who can generate FASSD COAs that support a greater range of post H-hour contingencies is more likely to achieve superiority [Metric: number of FASSD branches that can be developed for each COA].
Comprehensibility [4]: the commander who can produce more explainable COA to their staff (i.e., subordinates understand logic of COA, and are ‘comfortable’ executing it) is more likely to achieve superiority. [Metric: subordinate assessment ratings of COA suitability].
Mental workload [5]: the commander and their subordinates that can maintain lower levels of mental workload during and after planning are more likely to achieve superiority [Metric: individualand average staff ratings of self-reported mental workload].

Conclusion: We offer a set of proxy measures that could be used as indicators of a commander’s ‘appreciation superiority’ in planning operations. Further research is needed to test the reliability of these proxy measures in operational settings, and to explore their utility for designing tools and interventions that may help commanders out-think and defeat adversaries.

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References:

Australian Army (1987). *A guide to the tactical appreciation*. Land Warfare Centre.

Temby, P., Antoniades. M., Krastev. M., & Thiele. L.G. (2017). *Assessing Commander Decision Making with a Bright Fox - What a Cunning Plan!* Paper presented at the Defence Human Sciences Symposium 2017, Adelaide, South Australia.

Temby, P., & Thiele. L.G. (2018). *Enhancing Army Training and Education with the Bright Fox System.* Proceedings of the 2018 International Conference on Science and Innovation for Land Power (ICSILP), Adelaide, South Australia.

Thiele, L.G., & Temby. P. (2019). *Developing Army Decision Support Tools from Meta-Strategies Mined from the Observed Reasoning of Tactical Experts*. Paper presented at the Defence Human Sciences Symposium 2019, Canberra, ACT.

Notes:

[1] A COA is feasible if it can be achieved in the time and resources available. A COA is acceptable if it balances cost and risk with the advantage gained through execution. A COA is suitable if it can be executed in alignment with the higher commander's intent and planning guidance. A COA is sustainable if it can be executed with the combat service support elements available. A COA is distinguishable if it is significantly different from other possible COAs. Speed aids in defeating the enemy by allowing a commander to react before the enemy can respond or complete their appreciation, thereby forcing the enemy to re-plan under pressure.

[2] Simplicity minimises ‘friction’ thereby increasing the speed of execution and reducing opportunity for errors that might be exploited by the enemy.

[3] Planning should consider a greater range of contingencies (increased breadth) and extend through mission completion to consider force posture for follow-on tasks (achieve sufficient planning depth in time and space).

[4] As a proxy for recognising “better” COAs, a COA should be more readily “explainable” to subordinates, such that they understand the logic of the COA, can visualise and follow the relevant COA elements, and are “comfortable” with executing the COA.

[5] Given that operational environments typically involve a continual series of missions, reduced mental workload allows for greater total performance by conserving cognitive capacity and energy for longer.

A method to define athlete manoeuvrability in field-based team sports

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Background: This study presented a method of quantifying the manoeuvrability of two field-based team sportathletes and investigated its relationship with running velocity during competition.

Aim: The purpose of this study was to propose a measure of manoeuvrability known as tortuosity, and toinvestigate its relationship with running speed in field-based team sports.

Method: Across a season, 10 Hz Global navigation satellite system (GNSS) devices were worn during matchesby 62 athletes (Australian Football League [AFL]; n = 36, 17 matches, National Rugby League [NRL]; n= 26, 21 matches). To quantify manoeuvrability, tortuosity was calculated from the X and Ycoordinates from match GNSS files (converted from latitude and longitude). Tortuosity was calculated as 100 x natural logarithm of the chord distance (distance travelled between X and Y coordinates), divided by the straight line distance. The maximal tortuosity was then quantified for each 0.5 m□s^{-1} speed increment, ranging from 0 to the highest value for each game file. A quadratic model was fitted for each match file, controlling for the curvilinear relationship between tortuosity and velocity. A comparison of the quadratic coefficients between sports, and within sport between positions was investigated using linear mixed models. Resulting standard deviations (SDs) and meandifferences were then assessed to establish standardized effect sizes (ES) and 90% confidence intervals (CI).

Results: A curvilinear relationship exists between maximal tortuosity and running speed, reflecting that as speed increases, athletes' ability to deviate from a linear path is compromised (i.e., run in a more linear path). Compared to AFL, NRL had a greater negative quadratic coefficient (a) (ES = 0.70; 0.47to 0.93) for the 5 second analysis, meaning that as speed increased, NRL athletes' manoeuvrability reduced at a faster rate than when compared to AFL. There were no positional differences within eachsport.

Conclusions: GNSS derived information can be used to provide a measure of manoeuvrability during NRL and AFL matches. The curvilinear relationship between tortuosity and speed demonstrated that as speed increased, manoeuvrability was compromised.

Strategy use with an optimal observer aid in noisy multiple-cue judgments

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Abstract:
Automated target detection aids can assist military operators making complex, time sensitive judgments such as identifying friend from foe. Previous research has shown, however, that human operators fail to integrate information optimally from multiple sources, including cues from an aid. The experiment sought to determine how participants integrated information from noisy indictors anddecision aids to determine whether a friendly or hostile source was present. In the present task, operators were repeatedly asked to classify a signal as being from a friendly, civilian, or hostile source, using cues presented as three independent, noisy indicators. In some blocks of trials, operatorswere additionally given a decision aid (a Bayesian optimal observer) that indicated the most likely classification and its likelihood. Operator decision strategy use was inferred from computational modelling of respondent behaviour. The best-fitting model allowed independent parameters to governfriendly or hostile judgements, with civilian judgments being treated as the default response option. Models that applied the same parameters or decision rule to all judgment types (such as take the best or inferred base-rate) generally performed more poorly. People appeared to use different criteria when determining whether a signal contained a friend or hostile signal, even when given the same information format and decision aid.

Assessing lower limb running biomechanics using inertial measurement units

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Background: Assessing the biomechanics of human gait (i.e., walking, running) has important implications for understanding performance and injury risk. Furthermore, assessing human locomotion is routinely used to monitor the effects of, and recovery from, numerous conditions, particularly pathologies with a neurological or musculoskeletal origin. The gold standard assessment of human gait biomechanics, 3-dimensional (3D) optical motion capture, requires a specialised laboratory and highly skilled technical expertise to collect and analyse data, which limits it's accessibility, particularly in the field. Inertial measurement units (IMUs), small wearable sensors which fuse together accelerometry, gyroscope and magnetometer data streams, are becoming an increasingly common method to collect biomechanical data in the field. Emerging work has assessed the validity of IMUs to measure lower limb joint kinematics (i.e. joint angles) during walking and jogging, when compared against 3D optical motion capture, with promising results. It is unknown whether IMUs are a valid tool to measure lower limb kinematics during higher velocity locomotion, such as running and sprinting.

Aim: To determine the criterion validity of IMUs to measure lower limb kinematics during running and sprinting, when compared to 3D optimal motion capture.

Method: Twenty participants will be recruited for a criterion validity trial. Inclusion criteria includes: at a minimum recreationally active; male or female; aged between 18 and 40 years; not suffering from a lower limb injury at the time of testing. Participants will complete a familiarisation session followed (a minimum of three days later) by a data collection session. The data collection session will entail participants running at 70, 80, 90 and 100% of maximum velocity on an instrumented treadmill in a 3D optical motion capture laboratory. Prior to completing the running trials participants will be fitted with retroreflective motion capture markers on lower body anatomical landmarks in addition to seven IMUs (one on each foot, shank and thigh and one on the sacrum). The root-mean-square error (RMSE) of hip, knee and ankle sagittal plane kinematics between the IMU and optical motion capture systems will be determined across five consecutive gait cycles at each running speed.

Results: This study is a work-in-progress and results will be available for presentation at the Defence Human Science Symposium.

Conclusions: Validating methodologies that enable the biomechanical assessment of human running and sprinting in the field will allow for a greater capacity to capture this data on larger participant pools, which will be important for studies related to running performance and pathologies where running is implicated in the aetiology or the recovery.

Semi-Active Low-Profile Assistive Arm-Exoskeleton System with an Adaptive Configuration

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Background: Military personnel perform physically demanding tasks such as load carriage, weapon handling, and camp setup with musculoskeletal effects ranging from fatigue to acute and chronic injury(e.g. elbow tendinitis). Sustained muscular fatigue can cause muscle injuries (Allen and Westerblad, 2001). It destabilises the ability to sense and control joint position and leads to overworked muscles (Carpenter et al., 1998). Constant muscle overwork leads to cumulative trauma, which leads to muscleand bone strain injuries (Yoshikawa et al., 1994, Mair et al., 1996). Exoskeletal systems support and strengthen user joints and muscles, thus, significantly reducing physical demands. However, most exoskeletons struggle to accommodate slight variation in functionality from their original design. Thisposes a complex issue because many strenuous or labour-intensive tasks experienced by military personnel are rarely singular often encountering unusual but necessary movements. Therefore, an efficient exoskeleton requires personalisation to the user, with the capability of accommodating a variety of tasks, or at least, allowing full body movements without impediments.

Aim: This work proposes the design and evaluation of a novel, semi-active, elbow exoskeleton with an adaptive harness and actuation system to assist elbow flexion and brace the elbow joint of military personnel.

Method: Four scenarios of an arm holding different weights at the wrist, with and without exoskeleton assistance, were simulated in MATLAB/Simulink. The deviation between the inputted torque and induced torque by gravity was assessed to determine exoskeleton effectiveness. Physical implementation was assessed using rapid fabrication prototyping, stress and displacement analysis, andcomparison against mean anthropometric data.

Results: The proposed exoskeleton has a 290g mass with an adjustable harness system, whichaccommodates a wide range of user anthropometrics. From simulation results, it was observed that theexoskeleton places a 0.07Nm load increase on the elbow joint. However, this extra load is compensated by the actuation mechanism. When lifting 20N, the system decreased flexion torque from 5.12Nm to 4.1Nm (20%). Similar results were seen in subsequent simulations. Although little assistance was provided when lifting 125N, the exoskeletal structure benefits the user by means of skeletal support. The exoskeleton frame can withstand the produced 25Nm load and so provides the user a secondary means of joint safety. The 25Nm load produced a 0.1075mm displacement in the exoskeleton forearm.The displacement is hypothesised to be negligible in terms of causing strain on the user forearm and elbow joint. During muscle relaxation, exoskeleton actuation slightly lifted the forearm from standard resting position, thus, carrying the limb. Due to harness anchor points being on the user's body, it is suggested to disengage the actuation mechanism when unneeded to reduce contact pressure over time.

Conclusions: The proposed exoskeleton contains a lightweight, compact, and user-friendly exoskeleton system with adaptive actuation, three harnessing points, and modular harness cuffs. Simulation and experimental evaluation were conducted to assess the effectiveness of the system. It was observed thatthe exoskeleton can accommodate most arm anthropometrics and provide assistive torque for elbow flexion, which reduces stress and fatigue on the human elbow joint and muscles during flexion.

References:

Allen, D. G. & Westerblad, H. (2001). Role of phosphate and calcium stores in muscle fatigue. *The Journal of physiology,* 536**,** 657-665.

Carpenter, J. E., Blasier, R. B. & Pellizzon, G. G. (1998). The effects of muscle fatigue on shoulder joint position sense. *The American journal of sports medicine,* 26**,** 262-265.

Mair, S. D., Seaber, A. V., Glisson, R. R. & Garret JR, W. E. (1996). The role of fatigue in susceptibility to acute muscle strain injury. *The American Journal of Sports Medicine,* 24**,** 137-143.

Yoshikawa, T., Mori, S., Santiesteban, A.J., Sun, T.C., Hafstad, E., Chen, J. & Burr, D. B. (1994). The effects of muscle fatigue on bone strain. *Journal of Experimental Biology,* 188**,** 217-233.

Expertise and Skill Learning Knowledge Can Accelerate Performance of Soldiers

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Humans are capable of achieving exceptional motor skill performance under significant constraints of high time stress, psychological pressure, and minimal error tolerance in a variety of domains (Ericsson et al., 2018). For example, expert cricket batsmen are capable of batting for several hours ordays without making a single skill error that might result in them being dismissed. Similarly, a soldier can be required to carry out their mission for several days with no error that could otherwise cause injury or be fatal. The purpose of this paper is to introduce the field of expertise and skill learningwith a view that its knowledge and techniques can be used to accelerate a soldier's performance. The field of expertise seeks to understand the mechanism(s) that differentiates superior from inferior perceptual-cognitive-motor skill performance. In turn, the field of skill learning seeks to understand the principles of practice, instruction, and feedback that facilitates improvement in performance (learning), as well as retention and transfer of improvements to field settings. Knowledge from these fields can provide a unique opportunity to assess and accelerate performance improvement across the skill continuum of soldiers. Accordingly, this paper will provide an overview of how expertise knowledge, instruments, and learning principles can be used to enhance the visual-perceptual-motor skills of soldiers. This paper will use sport as the exemplar, with reference to the military domain, because athletes execute their skills under similar constraints to soldiers indicating that the underpinning mechanisms are transferable. This paper is structured into three sections. First, an introduction will be provided to the field of expertise and instruments used to assess visual- perceptual-motor skill. Here, key factors that discriminate performance such as pick-up of visual cues in the immediate environment to anticipate and make critical decisions under high time stress will be discussed (Morris-Binelli & Müller, 2017). These expertise skills are crucial because athletes and soldiers are required to use contextual, as well as opponent (or enemy) kinematic cues that are deceptive to guide accurate action responses. Second, principles that facilitate learning and transfer from laboratory to field settings will be discussed. This content will include design of simulators such as video or virtual reality and field-based practice tasks. Here, the importance of including contextual and kinematic information, as well as utilisation of an individual differences approach to design anticipation and decision-making training tasks will be discussed (Morris-Binelli et al., 2021). Third, future research directions will be suggested based upon an interdisciplinary approach that includes an intertwined psychological and physical individual differences training approach to enhance performance (Piggott et al., 2020). Collectively, it is hoped that through this paper, the common mechanisms that bind sport and military performance domains will be elucidated to forge future collaborations.

References

Ericsson, A., Hoffman, A., Kozbelt, A., & Williams, A. M. (Eds.). (2018). *Cambridge handbook of expertise and expert performance* (2nd ed.). Cambridge University Press.

Morris-Binelli, K., & Müller, S. (2017). Advancements to the understanding of expert visual anticipation skill in striking sports. *Canadian Journal of Behavioural Science*, *49*(4), 262- 268. https://doi.org/10.1037/cbs0000079

Morris-Binelli, K., Müller, S., van Rens, F. E. C. A., Harbaugh, A. G., & Rosalie, S. M. (2021). Individual differences in performance and learning of visual anticipation in expert field hockey goalkeepers. *Psychology of Sport and Exercise*, *52*, Article 101829. https://doi.org/10.1016/j.psychsport.2020.101829

Piggott, B., Müller, S., Chivers, P., Cripps, A., & Hoyne, G. (2020). Interdisciplinary sport research can better predict competition performance, identify individual differences, and quantify task representation. *Frontiers in Sports and Active Living*, *2* Article 14. https://doi.org/10.3389/fspor.2020.00014

Effect of load carriage on gait variability: a case study

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Background: Load carriage is a common requirement for many military personnel; however, load carriage is associated with injuries. Orr et al. (2017) found that among Australian soldiers the majority of load carriage-related injuries were to the lower limbs (61%) with bones and joints the most frequently injured body structures (39%); where the task of endurance marching accounted for most (38%) injuries.

It has been suggested that motor variability between strides (e.g., variability of coordination between segments) is beneficial as it is an expression of motor flexibility and allows for balanced accumulation of stresses across tissues, and the capacity for motor system to adapt to any changes that arise in the environment (Hamill et al., 1999). However, motor variability has been found to increase with fatigue and with the application of heavy loads (Qu et al., 2011) and to have adverse effect on motor performance (Birell et al., 2009). The uncontrolled manifold (UCM) theory (Scholz et al., 1999) is a method that quantifies variability as "good" (not affecting performance) or "bad" (affecting performance). The effect of conditions on certain tasks can be assessed based on changes to this variability structure (Qu, 2012).

Aim: The purpose of this study was to use the UCM analysis to investigate the effects of load carriage on gait variability. Based on previous evidence (Qu, 2012), we hypothesized that increased load carriage would lead to decreased good variability (V_{UCM}), and increased bad variability (V_{ORTH}), and decreased
V_{RATIO} $(\frac{V_{UCM}-V_{ORTH}}{V_{UCM}+V_{ORTH}})$.

Method: This study received ethics approval (343-21). Kinematic data from a 4 segments model (pelvis, right thigh, right shank, right foot) was collected from one participant walking on an instrumented treadmill at comfortable speed (4km/h; 1.1m/s) for 10min, in six loading conditions: no weight, 10%, 20%, 30%, 40%, 50% added body mass. Conditions were randomly presented. We analysed the pelvis COM (proxy for full-body COM) data through the stance time of the last 50 strides, and the UCM analysis was carried out in the vertical and horizontal component, separately. The dependent measures were UCM variability measures (V_{UCM}, and V_{ORTH}) and V_{RATIO}. Multiple One-way ANOVA were performed to determine the main effect of carrying load on the dependent measures. Tukey's post-hoc test was used to determine differences in the effects of different levels of load carriage. The level of significance $\alpha = 0.05$.

Results: The results from ANOVA showed that load carriage significantly affected vertical V_{UCM} ($F_{(5, 59)} = 17.934$, $p < 0.001$), vertical V_{RATIO} ($F_{(5, 59)} = 4.190$, $p = 0.003$), horizontal V_{UCM} ($F_{(5, 59)} = 10.654$, $p < 0.001$), and horizontal V_{ORTH} ($F_{(5, 59)} = 4.824$, $p = 0.001$). Post-hoc comparisons indicated that both vertical and horizontal V_{UCM} stay stable until 30% added mass, then it increases statistically; for vertical V_{RATIO}, the baseline condition was statistically lower than 30-50% conditions.

Conclusions: A threshold may exist (30% added mass) above which the task demand results in instability of performance with implication for injury risk. Further data is going to be collected to substantiate these findings.

References:

Orr, R. M., Coyle, J., Johnston, V., & Pope, R. (2017). Self-reported load carriage injuries of military soldiers. *International journal of injury control and safety promotion*, 24(2), 189-197.

Hamill, J., van Emmerik, R. E., Heiderscheit, B. C., & Li, L. (1999). A dynamical systems approach to lower extremity running injuries. *Clinical biomechanics*, 14(5), 297-308.

Qu, X., & Yeo, J. C. (2011). Effects of load carriage and fatigue on gait characteristics. *Journal of biomechanics*, 44(7), 1259-1263.

Birrell, S. A., & Haslam, R. A. (2009). The effect of military load carriage on 3-D lower limb kinematics and spatiotemporal parameters. *Ergonomics*, 52(10), 1298-1304.

Scholz, J. P., & Schöner, G. (1999). The uncontrolled manifold concept: identifying control variables for a functional task. *Experimental brain research*, 126(3), 289-306.

Qu, X. (2012). Uncontrolled manifold analysis of gait variability: effects of load carriage and fatigue. *Gait & posture*, 36(2), 325-329.

P3R - The Whole Blood Fatty Acid Profile and the Omega-3 Index of Australian ArmyRecruits over the Course of Basic Military Training.

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Background: Basic military training (BMT) is physically stressful and cognitively demanding, placing an accumulating physiological strain on recruits (Tanskanen et al. 2011). Nutrition is therefore crucial for recruits during BMT. With an emphasis on total energy provision, nutritional strategies most often emphasise carbohydrates and protein provision for endurance, strength, power and recovery (Burke 2001). The profile of fat intake is rarely considered, despite the importance of consumed polyunsaturated fatty acids (PUFA), especially long chain omega-3 (LC n-3) PUFA eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) derived from seafood, on: membrane composition and function in heart and skeletal muscle; inflammation; and cardiovascular disease risk. The erythrocyte Omega-3 Index (O3I), a marker of the membrane concentrations of EPA and DHA inexcitable tissue, has a desirable target >8% (Harris and Von Schacky 2004) for low cardiovascular risk and optimal health and physiological function.

Aim: To describe the whole blood fatty acid profile and Omega-3 Index (O3I) of Australian Army recruits upon commencement of BMT and in response to consuming the provided mess diet over the duration of the course.

Method: Eighty (80) male (17-34 y, 77.4±13.0 kg, 43.5±4.3 mL/kg/min) and 37 female recruits (17- 45 y, 64.3±8.8 kg, 39.3±2.7 mL/kg/min) volunteered to participate in the study (N=117). The whole blood fatty acid profile and erythrocyte O3I of each recruit was determined in weeks 1 and 11 (n=82) using a finger prick blood sample. Samples were analysed via gas chromatography and the relative proportions of each fatty acid was quantified (mean [95% CI]). The macronutrient characteristics of two typical diet offerings (17 MJ/ day) was assessed using the mess menu over 14 days. These diets were described respectively as maximising and minimising food sources containing omega-3 fatty acids.

Results: Recruits at week 1 exhibited low omega-3 status (whole blood omega-3; 4.95% [4.82-5.07]) and O3I (5.03% [4.90-5.16]). No recruit recorded an O3I >8% (desirable). Ratios of omega-6/omega- 3 (7.04 [6.85-7.23]) and arachidonic acid /EPA (AA/EPA) (18.70 [17.86-19.53]), indicative of inflammation susceptibility, were in the high (undesirable) range for the cohort. The BMT mess menucould provide a maximum of 190 mg/day EPA and 260 mg/day DHA if omega-3 sources were alwaysselected. At week 11 the O3I of the recruits (4.62% [4.51-4.78], $p<0.05$) was lower, the omega- 6/omega-3 ratio (7.27 [7.07-7.47] $p<0.05$) increased, and the AA/EPA ratio (17.85 [16.89-18.81]) remained high.

Conclusion: These young recruits commenced BMT with low O3I and whole blood fatty acid profiletypical of a Western-style diet. The BMT diet, providing only intermittent seafood options, was low in LCn-3PUFA and further diminished EPA, DHA and the group mean O3I to less than 5%; a value associated with long-term implications for health and wellbeing, including cardiovascular disease risk. The low O3I and high ratios of key omega-6 to omega-3 PUFA is sub-optimal for muscle and cardiac composition in recruits undergoing the physical rigors of military training, and longer-term may put these young adults at elevated risk of cardiovascular disease.

References:

Burke, L.M. (2001) Nutritional Practices of Male and Female Endurance Cyclists. Sports Medicine. 31(7): 521-532.

Harris, W., and Von Schacky, C. (2004) The Omega-3 Index: a new risk factor for death fromcoronary heart disease? Preventative Medicine 39: 212-220.

Tanskanen, M.M., Uusitalo, A.L., Kinnunen, H., Hakkinen, K., Kyrolainen, H., and Atalay, M. (2011) Association of military training with oxidative stress and overreaching. Medicine, Science,Sports and Exercise. 43(8): 1552-1560.

Reliability of Sparta Science assessments in Army personnel

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Background: In the Australian Defence Force, 40% of clinical presentations are attributed to preventable musculoskeletal injuries. Interest in the use of specialised systems for the identification and reduction of risk for musculoskeletal injury has increased recently. One of these systems is from Sparta Science that assesses lower limb power, core stability and balance using a force plate and proprietary machine learning algorithms. Prior studies have reported variable levels of reliability for selected Sparta Science assessments in high school, college and professional athletes. A greater understanding of the reliability of the Sparta Science assessments within military settings will inform its potential use to enhance physical performance and reduce musculoskeletal injury risk.

Aim: To identify the reliability of Sparta Science assessments of lower limb power, core stability and balance in Army personnel.

Method: Following a standardised warm-up, Army personnel completed assessments of 1- and 2-leg lower limb power via countermovement jump, core stability via 1-arm plank, and 1-leg balance using the Sparta Science technology. Assessments were completed initially and 3-14 days later. The project is in progress with preliminary results to be discussed.

Autonomous Systems Reducing the Burden of Last Mile Logistics Resupply

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Background: Autonomous systems' capabilities are increasingly sought after and provide opportunities for increased efficiency, reduced safety risk, and reduced cognitive and physical burden. With a view to supporting these advantages in Defence, Frazer-Nash Consultancy have developed the Route Environment and Asset Resupply Manager (REARM).

REARM was initially developed to support Autonomous Last Mile Resupply Systems (ALMRS) in the land environment in 2017 and has been successfully demonstrated in the UK's Autonomous Warrior Experiment (2018), and the US Exercise Northern Strike (2019). To alleviate the cognitive burden of managing last mile logistics resupply, REARM ingests data from a range of mapping and battlefield intelligence sources and autonomously processes that information.

Methodology and Results: Frazer-Nash is continuing to develop REARM and is tailoring it for Australian specific use cases. Through the D.START incubator program, run by DST and CSIRO, several hypotheses pertaining to the value proposition of REARM to the Australian Defence Force have been confirmed via stakeholder interview. These are listed below.

- Logistics is a real and complex problem facing the Australian Army. Routing and allocation of logistics resupply places a significant cognitive burden on logisticians and reduces spirit within a cohort by requiring manual completion of high pressure but mundane, repetitive tasks. The problem also creates a significant physical burden, exposing logistics deliverers to possible injury or exposure to enemy fire.
- Operations in communications and GPS denied environments are expected, and bandwidth of operational communications is limited. There will always be connectivity challenges in the battlefield.
- Automated off-road route finding for a variety of vehicles is highly desirable.
- Trust is an essential component in determining whether the outputs of an AI system will be accepted. An AI system that is not trusted adds to the cognitive burden by increasing workload and introducing uncertainty.

Complex and abstract scenarios continually arise in the battlefield, and a commander must retain the authority to execute tactical decisions. AI and RAS (Robotic and Autonomous Systems) excel in human-machine teaming environments where the commander fills the complex "doing" role, and AI fills a "supporting" role, accelerating relatively simple problems while retaining operator trust.

Conclusions and Future Work: The concept of supporting and doing roles is difficult to define but is crucial to assuring the performance of the AI system. AI in a doing role will alleviate the entire cognitive burden for its task but has the potential to do more harm than good. There are more opportunities to prevent AI from acting on bad data when it is in a supporting role, but conversely this may increase the cognitive burden on users.

As we continue to develop REARM, we will be striving to understand how to differentiate between supporting and doing in a human-machine teaming context. We welcome opportunities to collaborate with industry and research partners to further the AI community's understanding of this problem.

Conceptualising the Work Domain of Human-Machine/AI Teams in the Future Force

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Background: Technologies are rapidly improving and increasingly being considered more than just tools; Artificially intelligent (AI) machines may soon function as team members. The Australian Defence Force (ADF) are investigating emerging technologies whilst developing associated operating concepts, and requirements for their impending acquisition intended for use in near and distant futures.

To design Human-Machine/AI teams for the future, two key problems must be resolved. First, the specific situations that teams will operate in are uncertain, making it difficult to predict or specify the tasks or challenges to accommodate in design (Naikar, Moy, Kwok, & Brady, 2021). Second, the ADF is large andcomplex, with varied teams with different purposes and requirements.

Methodologies that prescribe or describe work (e.g., Kirwan, & Ainsworth, 1992), would be reliant on *assumed* information about the operating situation, and thus diminish confidence in the results. Alternatively, a cognitive work analysis identifies the boundaries of successful operation independently of situations, tasks, events, or goals (Vicente, 1999). It differentiates what is and is not possible in the work domain (WD), given the boundaries, thereby revealing the space of possibilities for action regardless of specific conditions. In the first stage, the WD is defined through contextual constraints placed on actors, whether humans or machines, within the domain.

Aim: The aim was to define the WD of Human-Machine/AI teams with sufficient fidelity to understand thedifferent constraint considerations applicable to different types of teams across the ADF.

Method: The WD was positioned in a future space and time utilising an "envisioned world" developed by Ong & Naikar (2021). A notional Army team was utilised to assure applicability of the model at the team level, establish the required level of fidelity, and to ensure the nuances of different teams were accommodated. The definition of the WD was achieved by exploring the analytic themes outlined by Naikar(2013).

Results: A critical challenge identified in this application of WD analysis was how the boundaries of the analysis could be defined so that the resulting model accommodated multiple teams within the ADF, whileaccommodating the nuances of different teams.

The WD was defined by conceptualising a 'Location of Priority Action' (LPA), and considering where teams could exist in relation to it. Teams at different conceptual locations relative to the LPA share sufficiently similar WD properties, allowing them to be grouped. These groups are: *Engagement Actors*: those applying effects at the LPA; *Support Actors*: those directly supporting the Engagement Actors; and *Enabling Actors*: those enabling all actions indirectly. In addition, a domain of *Non-Controlled Actors* was considered suitable for capturing other relevant considerations such as adversaries and the environment.

Conclusions: By conceptualising the work domain of future Human-Machine/AI teams in this way, a single framework is provided that organises teams based on their notional functions, according to their conceptual proximity to direct military action. This conceptualisation provides sufficient fidelity to enable development of subdomain models at finer levels of granularity, focusing on particular teams of interest, as required. An initial test of this approach will occur when evaluating the Army's Semi-Autonomous Combat Team concept (Sawers, & Tang, 2020) in the field.

References:

Kirwan, B., & Ainsworth, L.K. (Eds.). (1992). A Guide To Task Analysis: The Task Analysis Working Group (1st ed.). CRC Press. https://doi.org/10.1201/b16826

Naikar, N. (2013). Work Domain Analysis: Concepts, Guidelines, and Cases (1st ed.). CRC Press. https://doi.org/10.1201/b14774

Naikar, N., Moy, G., Kwok, H-W., & Brady, A. (2021). Designing for "agility" in an envisioned command and control worlds: Concepts for collaborative intelligence in human-machine teams. Proceedings of Naturalistic Decision Making and Resilience Engineering Symposium. Toulouse, France.

Ong, R., & Naikar, N. (2021). Designing collaborative intelligence teams for agility in an envisioned command and control world. Submitted for publication.

Sawer, M & Tang, K. (2020). Semi-Autonomous Combat Team Dismounted Infantry 2030 Concept. DST- Group-GD-1068, [General Document] Defence Science and Technology Group Australia

A Closed-Loop AR-based System for Real-World BCI Application

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Introduction: The field of human-robot interaction (HRI) is constantly evolving and adapting to assist human performance, especially in various fields such as drone control and social robots. Many existing studies have developed systems that leverage Brain-Computer Interface (BCI) to read people's minds (Making et al., 2020; Xu et al., 2019; Lin et al., 2019). The BCIs are wired together toprovide real-time communication between all devices in most cases. Similarly, studies infrequently require users to assess their physical surroundings before interacting with the BCI. These barriers have limited the BCI usage in real-world HRI (Si-Mohammed et. al., 2020; Putze et. al., 2019).

Aim: This study attempts to build a portable and closed-loop BCI approach for stable and reliable HRI in which Augmented Reality (AR) can incorporate BCI stimuli and real-time feedback in real-world surroundings.

Method: The steady-state visually evoked potential (SSVEP) BCI was implemented as an AR scenario to Microsoft HoloLens 2 to control an unmanned aerial vehicle, TurtleBot 3. The g.tec Unicorn Black 8-ch EEG system (250 Hz sampling rate) and one portable computer were used to capture brain dynamics and decode brain signals (O1, Oz, O2) through canonical correlation analysis(CCA), respectively. All hardware was communicated through Bluetooth and WIFI. Three participants aged 22-25 (one female) involved in this experiment due to COVID restriction. The experimental protocol was reviewed and approved by UTS Human Research Ethics Committee (ETH20-5371). The participants were asked to control the TurtleBot 3 accurately and precisely to reach one of nine destinations by selecting the correct comments through SSVEP. Every participant needed to reach the random destinations 70 times within limited steps, and 3.4 SSVEP comments should be used to reach the destination.

Results: Results showed that this portable and closed-loop AR-based BCI system could have reliable HRI. Destination accuracy and SSVEP accuracy were used to assess the performance of this portable AR-based BCI performance system. The current data show 100% destination accuracy and 88% SSVEP accuracy. Particularly, one participant reaches 100% for both destination and SSVEP accuracy.

Conclusions: This study demonstrated a fully portable BCI and functional control system for an autonomous agent (robot) over a wireless network connection. Additionally, the AR interface provides a standardised platform capable of hugely dynamic interfaces. One benefit of the current solution is the existing wireless transmission, allowing the proposed system to be integrated into any networked device. Moreover, a built-in eye-tracking sensor can bring more feasibilities to HRI with reliable system performance and a higher information transfer rate. The research team intends to extend this portable AR interface and closed-loop BCI system for more real-world applications whichcan boost human performance and decision making.

Reference:

Makin, J.G., Moses, D.A. & Chang, E.F. (2020). Machine translation of cortical activity to text withan encoder-decoder framework. Nature Neuroscience, 23, 575–582.

Xu, D., Songyun X., Xinzhou, X., Ya, M., Zhao, X. (2019). Quadcopter Flight Control Using a Non-invasive Multi-Modal Brain Computer Interface. Frontiers in Neurorobotics, 13, 1662-5218.

Lin, C. T., Chiu C. Y., Singh, A. K., King J. T., Ko L., W., Lu Y. C. and Wang Y. K. (2019). A Wireless Multifunctional SSVEP-Based Brain–Computer Interface Assistive System. IEEE Transactions on Cognitive and Developmental Systems, 11(3), 375-383.

Si-Mohammed, H., Petit, J., Jeunet, C., Sanz, F A., Spindler, F (2020). Towards BCI-based Interfacesfor Augmented Reality: Feasibility, Design and Evaluation. IEEE Transactions on Visualization and Computer Graphics, Institute of Electrical and Electronics Engineers, 26(3), 1608-1621.

Putze F., Weiß D., Vortmann L. and Schultz T. (2019). Augmented Reality Interface for Smart HomeControl using SSVEP-BCI and Eye Gaze. IEEE International Conference on Systems, Man and Cybernetics (SMC), 2812-2817.