MEASUREMENT OF COGNITIVE FITNESS IN REALISTIC CONTEXTS

Problem

Cognitive fitness (CF) is a key element of personnel operational readiness, and fundamental to the long-term sustainment of the force. CF impacts training and operational outcomes, and likely to drive career trajectories. Following the establishment of an expert consensus on key dimensions of CF, such as attention control, working memory and arousal regulation [1], multiple IS&T initiatives are underway developing best-practice methods to measure [2,3], improve and augment CF [4-8]. The AUSMURI "Building Cognitive Capability" discovery projects (USD15M from ONR + $4M from ASCA) are generating measurement standards and neuro-cognitive modelling tools to support these applications.
These developments have yet to be consolidated into fieldable technologies to assess the warfighter's CF, monitor it through training and protect it under operational conditions. The technologies critically dependent on CF measurement include (1) digital training platforms (e.g., Cognitive Gym [4,6,7]), (2) biomarker-enhanced cognitive monitoring devices [9, 10], (3) tactical cognitive enhancers (e.g., caffeinated chewing gum [11]), and (4) cognitive recovery tools (e.g., circadian optimisation [5]).

Need and relevance to Defence

CF measurement is key to sustaining operational readiness [4], which is critical under the shrinking strategic warning time. As a known protective factor in mental health, CF assessment and monitoring can inform the long-term force preservation measure, help de-risk post-separation, assist the DVA in its duty of care, and radically improve Defence's response to RCDVS recommendations.

Research questions

Developing fieldable technologies and measurement protocols for the key elements of CF, is the next frontier. These protocols must be valid and reliable, yet realistic and able to produce actionable insights about user performance. The main challenge – and the focus of this problem statement – is to develop an ML-enabled CF measurement toolkit capable of integrating (1) robust bio-sensing such as cardio- and respiratory signals, (2) micro-action logging, such as eye-movement, voice and posture, and (3) subjective state markers such as facial expression, into a holistic and unobtrusive assessment of CF.
In particular, measures of respiratory function are now supported by quality lab sensors and mature inference algorithms, but are yet to transition to fieldable solutions employing consumer-grade hardware, such as smartphone headsets.

Note:

a. CF is the target measurement construct here – as distinct from measures of cognitive performance (which can be utilised in purpose-built protocols to quantify CF).

b. Dimensionality of CF construct is yet to be established, but likely to be multifactorial; an empirical test of CF dimensionality would strengthen proposals, with the expert consensus [1] as a starting point

Expected outcomes

The proposal should establish the validity of the proposed measurement tools and their utility in Defence-relevant applications with clearly defined time scales (baselining vs slow change vs real-time monitoring). Dual-use applications actively pursued in healthcare, sport and first responder industries, should be leveraged and shaped to meet Defence requirements.

Methodology/approach

Edge computing-based solutions are preferred, to minimise data transmission. Of particular interest are methods to monitor attention capacity (focus intensity, breadth and duration, shifting, susceptibility to distraction) and stress/arousal regulation (e.g., autonomic balance through heart rate and breathing patterns). CF measures should cover a wide range of complexity in cognitive tasks. If low-level measures are used (e.g., vigilance) they must offer inferences about higher-order tasks (e.g., attention and decision making)

Note that gold-standard measures of CF have yet to be established. Consequently, training datasets for ML exploitation currently unavailable; proposals to generate them are welcome

References

1. Albertella, L., Kirkham, R., Adler, A., Crampton, J., Drummond, S., Fogarty, G., ... & Yucel, M. (2022). Building a Transdisciplinary Expert Consensus on the Cognitive Drivers of Performance Under Pressure: An International Multi-panel Delphi Study. *Frontiers in Psychology,* 1017675.

2. Kucina, T., Wells, L., Lewis, I., de Salas, K., Kohl, A., Palmer, M., Sauer, J.D., Matzke, D., Aidman, E., & Heathcote, A. (2023). Calibration of cognitive tests to address the reliability paradox for decision-conflict tasks. *Nature Communications* 14 (1), 2234.

3. Kleitman, S., Jackson, S. A., Zhang, L., Blanchard, M., Rizvadi, N.N., & Aidman, E., (2022). Applying evidence-centred design for the measurement of psychological resilience: A novel simulation-based assessment methodology. *Frontiers in Psychology*, 12, 717568

4. Aidman, E., Fogarty, G.J., Crampton, J., Bond, J., Taylor, P., Heathcote, A. & Zaichkowsky, L. (2022). An App-enhanced Cognitive Fitness
Training Program for Athletes: The Rationale and Validation Protocol. *Frontiers in Psychology: Performance Science*, 13:957551.

5. Varma, P., Postnova, S., Knock, S., Howard, M. E., Aidman, E., Rajaratnam, S. W., & Sletten, T. L. (2024). SleepSync: Early Testing of a Personalised Sleep–Wake Management Smartphone Application for Improving Sleep and Cognitive Fitness in Defence Shift Workers. *Clocks & Sleep*, 6(2), 267-280

6. Taylor, P., Walker, F. R., Heathcote, A., & Aidman, E. (2023). Effects of Multimodal Physical and Cognitive Fitness Training on Sustaining Mental Health and Job Readiness in a Military Cohort. *Sustainability*, 15(11), 9016.

7. 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.

8. Matthews, R. W., Fogarty, G. J., Aidman, E., & Patrick, T. (2024). Optimising fatigue agility and recovery within military settings: Enhancing capability, well-being, and performance. In *Fostering Recovery and Well-being in a Healthy Lifestyle* (pp. 165-181). Routledge.

9. Walker, F.R., Thomson, A., Pfingst K., Vlemincx, E., Aidman, E., & Nalivaiko E. (2019) Habituation of the electrodermal response – a biological correlate of resilience? PLoS ONE, 14 (1), e0210078.

10. Aidman, E.V., Chadunow, C., Johnson, K., Reece, J. (2015). Real–Time Driver Drowsiness Feedback Improves Driver Alertness and Self-reported Driving Performance: A Repeated-measures Field Trial. Accident Analysis & Prevention. 81, 8-13.

11. Aidman, E., Balin, M., Johnson, K., Jackson, S., Paech, G. M., Pajcin, M., ... & Banks, S. (2021). Caffeine may disrupt the impact of real-time drowsiness on cognitive performance: a double-blind, placebo-controlled small-sample study. *Nature Scientific Reports*, 11, 4027 (2021).