
Behavioural Measurement of Cognitive Workload



by

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March 1, 2021

Statements

- *Originality:* I hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision. The thesis contains no material which has been accepted, or is being examined, for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968 and any approved embargo.
- *Authorship:* I hereby certify that the work embodied in this thesis contains published paper/s/scholarly work of which I am a joint author. I have included as part of the thesis a written declaration endorsed in writing by my supervisor, attesting to my contribution to the joint publication/s/scholarly work.

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By signing below I confirm that Reilly Innes contributed [insert description / outline of contribution] to the paper/ publication entitled [insert reference details]

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Acknowledgements

I referred to Song, Kang, Timakum, and Zhang (2020) for guidance on common acknowledgement practice and have thus limited my acknowledgements to follow the key patterns, and average length, as identified by the CNN+Doc2Vec algorithm, as well as relying on common example keywords (shown in *italics*).

1. Peer interactive communication and Technical support

First and foremost, I would like to thank my supervisor Professor Scott Brown and co-supervisor Associate Professor Ami Eidels for their continued *support* and belief in me throughout my honours and PhD candidacy. Further, I am thankful for all of the *academic assistance, fruitful discussions, valuable suggestions, insightful comments and resources* that you have provided. I will always see you as the ultimate academic role models.

I would also *like to acknowledge other academics* who in some way, shape or form contributed to this thesis – Dr. Z. Howard, Dr. N. Evans, Mr. A. Thorpe, Ms. C. Kuhne, Mr. G. Cooper, Dr. K. Nesbitt, Dr. L. Wall, Dr. P. Garrett, Dr. G. Hawkins, Mr. J-P. Cavallaro, Ms. G. Newcombe and Ms. J. Sparre; without your assistance this would have taken a lot longer.

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2. Financial

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3. General acknowledgement

Finally, I would like to acknowledge my loved ones. To my parents – *thank you for supporting me, encouraging* my curiosity, *teaching* me the important things in life and having a seemingly unlimited workload capacity. To my brother – thank you for always being the C to my R (literally). To Sarah – thank you for putting up with me and filling my heart as full as my workload in a four dots to track MOT paradigm. To my friends – thank you for providing the necessary rest breaks between blocks and feedback I needed. Thank you all for your support, which feels like one of my experiments to a participant – endless.

List of Publications

The work within this thesis has lead to the following journal articles that are either currently published, submitted, or in preparation, which I have listed with the full bibliographic citations in the order they appear in the thesis:

1. Howard, Z., Innes, R., Brown, S. D., & Eidels, A. (2018). Cognitive workload and analysis of flight path data. *Technical Report*
2. Innes, R., Howard, Z., Eidels, A., & Brown, S. D. (2018). Cognitive workload measurement and analysis. *Technical Report*
3. Innes, R. J., Howard, Z. L., Evans, N. J., Eidels, A., & Brown, S. D. (2020). A broader application of the detection response task to cognitive tasks and online environments. *Human Factors*. doi: <https://doi.org/10.1177/0018720820936800>
4. Innes, R. J., Howard, Z. L., Thorpe, A., Eidels, A., & Brown, S. D. (2020). The effects of increased visual information on cognitive workload in a helicopter simulator. *Human Factors*. doi: <https://doi.org/10.1177/0018720820945409>
5. Innes, R. J., & Kuhne, C. L. (2020). An LBA account of decisions in the multiple object tracking task. *The Quantitative Methods for Psychology*, 16, 175–191. doi: [10.20982/tqmp.16.2.p175](https://doi.org/10.20982/tqmp.16.2.p175)

Statement of Contribution

Below I have included a statement outlining both my contribution, and the involvement of others, for each chapter where the research performed involved collaboration. This addresses the requirements of both the *Statement of Collaboration* and the *Statement of Authorship*. The below statement have been endorsed by my primary supervisor, Professor Scott Brown.

Publication Contributions

Chapter 3

Innes, R. J., Howard, Z. L., Thorpe, A., Eidels, A., & Brown, S. D. (2020). The effects of increased visual information on cognitive workload in a helicopter simulator. *Human Factors*. doi: <https://doi.org/10.1177/0018720820945409>

- *Reilly Innes*: Planned design (25%), conducted study (35%), analysed results (45%), wrote paper (70%).
- *Zachary Howard*: Planned design (25%), conducted study (35%), analysed results (45%), wrote paper (20%), edited paper (20%).
- *Alexander Thorpe*: Conducted study (30%), analysed results (10%), wrote paper (10%), edited paper (10%).
- *Ami Eidels*: Planned design (25%), edited paper (40%).
- *Scott Brown*: Planned design (25%), edited paper (30%).

Chapter Contributions

- *Chapter 3:* I was involved in the development of the Experiments outlined in Chapter 3. In conjunction with Scott Brown, Ami Eidels and Nathan Evans, I designed the original DRT-MOT experiment (as part of another project which is now published – see Innes, Evans, Howard, Eidels, and Brown (2020)), which was extended in Chapter 3. Nathan Evans assisted with initial programming of the design. I completed all of the testing and analysis for Experiment 1. Gemma Newcombe and Jessica Sparre assisted with data collection and analysis for one of the subsequent experiments in Chapter 3. I programmed and analysed both of the subsequent experiments of Chapter 3, most of which is not included here for brevity, but can be found at <https://osf.io/ayp6d/>.
- *Chapter 5:* This project was work in collaboration with Airbus Helicopters and Hensoldt Sensor Systems. Airbus personnel proposed the initial problem (helicopter pilot overload). In collaboration with Zachary Howard, Scott Brown and Ami Eidels, I assisted in refining the research question and methodology. I also completed the literature review. Alexander Thorpe, Keith Nesbitt, Ami Ediels, Scott Brown, Zachary Howard and myself completed the data collection. Zachary Howard completed the majority of flight data analysis, whilst Alexander Thorpe also contributed. I completed the majority of DRT analyses. I was also responsible for producing a technical report of cognitive workload measurement (see Innes, Howard, Eidels, and Brown (2018)), and contributed to the technical report led by Zachary Howard for the flight data analysis (see Howard, Innes, Brown, and Eidels (2018)). I was involved as the lead author for the resulting publication (Innes, Howard, Thorpe, Eidels, & Brown, 2020), with comments from Zachary Howard, Ami Eidels, Alexander Thorpe and Scott Brown, whom are also co-authors on the publication. This chapter is published at *Human Factors: The journal of human factors and ergonomics society*.
- *Chapter 6:* I was involved in establishing the working relationship with the ADF group involved in testing, which has continued over the four years of my candidature. This project also had contributions from Zachary Howard, Ami Ediels and Scott Brown. I developed the experiment and proposed and conducted the analysis, and this was assisted by Ami Eidels and Zachary Howard. I collected data from the undergraduate

participants and was responsible for identifying similar and/or useful literature for this chapter.

- *Chapter 7:* I completed the literature review, analysis and writing for chapter 7. Caroline Kuhne assisted with model analysis and was a co-author of a resulting paper (see Innes and Kuhne (2020)). The paper is published at *The Quantitative Methods for Psychology Journal*. I conducted the joint model analysis using insights from this paper. Scott Brown provided comments and direction for the analysis and discussion. Gavin Cooper assisted with the sampling process.

Additional Publications

Listed are additional journal articles or internal reports that are either currently published, submitted, or in preparation, which I have been involved in during my candidature. These publications are listed here as they are closely related to the work shown in this thesis, however were part of different projects and/or theses.

1. Howard, Z. L., Evans, N. J., Innes, R. J., Brown, S., & Eidels, A. (2019, August 27). How is multitasking different from increased difficulty? *Psychonomic Bulletin and Review*. <https://doi.org/10.3758/s13423-020-01741-8>
2. Thorpe, A., Innes, R. J., Townsend, J., Heath, R., Nesbitt, K., & Eidels, A. (2020) Assessing Cross-Modal Interference in the Detection Response Task. *Journal of Mathematical Psychology*, 98, 102390.

Additional Work

Listed are additional publications and presentations which have relevance to the thesis, but are not included in it, or represent earlier iterations of included work. In each case, the presenter's name is written in **bold**:

1. **Innes, R. J.**, Eidels, A., & Brown, S. (2017). *Evidence for an Applied Measure of Cognitive Capacity in a Laboratory Environment*. Experimental Psychology Conference. Shoal Bay, NSW, AUS.
2. **Innes, R. J.**, Howard, Z. L., Eidels, A., & Brown, S. (2017). *An objective measure of cognitive workload: Evaluation and practical Application*. CBMHR Postgraduate Conference. Newcastle, NSW, AUS.
3. **Innes, R. J.**, Howard, Z. L., Eidels, A., & Brown, S. (2018). *Biting off more than you can process: Group differences in cognitive workload*. Experimental Psychology Conference. Hobart, TAS, AUS.
4. **Innes, R. J.**, Howard, Z. L., Thorpe, A., Eidels, A., & Brown, S. (2019). *Flying blind: Does adding information really help?* Australasian Mathematical Psychology Conference. Melbourne, VIC, AUS.
5. **Innes, R. J.**, Howard, Z. L., Eidels, A., & Brown, S. (2019). *A measurement tool for comparing cognitive workload differences* (poster). Society for Computers in Psychology Conference. Montreal, CAN.
6. **Innes, R. J.**, Kuhne, C. L., & Brown, S. (2020). *Modelling decisions of the multiple object tracking task*. Australasian Mathematical Psychology Conference. Coogee, NSW, AUS.
7. **Innes, R. J.**, & Brown, S. (2020). *Joint modelling group differences from military personnel*. 2020 Annual Meeting of the Society for Mathematical Psychology. Virtual Conference.
8. **Cooper, G.**, Cavallaro, J., Innes, R. J., Kuhne, C., Hawkins, G., & Brown, S. (2020). *Hierarchical Bayesian parameter estimation with the Particle Metropolis within Gibbs sampler*. 2020 Annual Meeting of the Society for Mathematical Psychology. Virtual Conference.

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Abstract

Everyday we are faced with a myriad of tasks to complete, ranging from the most simple to highly complex. Our ability to complete such tasks is limited by inherent mechanisms which allow us to focus our attention and perceive the optimal amount of information needed to do so. As more information becomes available, and as a result of our propensity to multitask, these cognitive limits are pushed and stretched. In doing so, we often ignore important task relevant information, or our performance is inhibited. To fully understand the interplay of these factors, we need to be able to measure and evaluate workload. In this thesis I investigate the construct of cognitive workload, which is inherently limited by our overall capacity, through a measure used predominantly in applied driver distraction literature. From this, I present a body of work that expands upon theoretical underpinnings and new applications of this measure. In the theoretical stream, I show the usefulness, reliability, and applicability, of this measure in lab-based scenarios, whilst in the applied stream, I show three novel uses of the measure in both theoretical and real-world scenarios, as well as developing analyses applicable to such scenarios. The research in this thesis has implications and applications across a broad range of research areas, ranging from theoretical, in areas such as methodological development, to highly applied, in areas such as aviation environment evaluation.

In the interest of openness and replicability, all data (from student cohorts)¹, analysis and further appendices from this thesis can be found at <https://osf.io/ayp6d/>.

¹RAAF group data (Chapter 6 and 7) is confidential and cannot be shared publicly. The same applies to data collected from Airbus Helicopters & Hensoldt Sensor Systems (Chapter 5).

“There are a great many people in the country today, who through no fault of their own, are sane. Some of them were born sane, while others became sane later in their lives. It is up to people like you and me, who are out of our tiny little minds, to help them overcome their sanity.”

– The Reverend Arthur Belling