Advancing Methods and Mathematical Models of Perceptual Decision Making

by

Gabriel Tillman

B.Psych (Hons I)

A thesis submitted in fulfillment of the requirements

for the degree of Doctor of Philosophy (Psychology - Science)

October 30, 2016

Declaration of Authorship

- The thesis contains no material which has been accepted 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 in the text. 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. **Unless an Embargo has been approved for a determined period.

- I hereby certify that the work embodied in this thesis has been done in collaboration with other researchers, or carried out in other institutions. I have included as part of the thesis a statement clearly outlining the extent of collaboration, with whom and under what auspices.

- I hereby certify that the work embodied in this thesis contains published papers scholarly work of which I am a joint author. I have included as part of the thesis a written statement, endorsed by my supervisor, attesting to my contribution to the joint publications scholarly work.

Signed:

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Acknowledgements

Where would I be without Don, Andrew, and Scott who made me the researcher I am today. I thank Ami who was always there to provide solid advice. And Adam for his enthusiasm and interesting pitches for future work. It was fun working with students in the lab who were always there to answers my questions, ask their own, and devise novel ways to procrastinate from work. All my collaborators taught me how to think critically and question everything. I am truly thankful for the support from all these people. To my wife Lucy, who has been caring, supportive, patient, thoughtful and loving, I give my deepest thanks.

List of Publications

This thesis is based on the following published/submitted work. For each paper I provide the full bibliographic citations in the order they appear in the thesis:

1. Tillman, G., Strayer, D., Eidels, A., & Heathcote, A. (Under Review). Modeling Cognitive Load Effects of Conversation Between a Passenger and Driver. Attention, Perception, & Psychophysics.

2. Tillman, G., Benders, T., Brown, S. D., & van Ravenzwaaij, D. (Under Review). An Evidence Accumulation Model of Acoustic Cue Weighting in Vowel Perception. Journal of Phonetics

3. Tillman, G., Osth, A., van Ravenzwaaij, D.,& Heathcote, A. (Under Review). A Diffusion Decision Model Analysis of Evidence Variability in the Lexical Decision Task. Psychonomic bulletin & Review

4. Tillman, G., Eidels, A., & Finkbeiner, M. (2016). A Reach-To-Touch Investigation on the Nature of Reading in the Stroop Task. Attention, Perception, & Psychophysics.

Statement of Contribution

I attest that Research Higher Degree candidate Gabriel Tillman led the manuscripts included in this thesis. Gabriel Tillman made major contributions to each manuscript including, coordinating and supervising data collection, completing all data analyses and model fitting, and served as lead author for manuscript preparation.

Name: Don van Ravenzwaaij

Signed:

Name: Andrew Heathcote

Signed:

Name: Scott Brown

Signed:

Name: Ami Eidels

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Name: Adam Osth

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Name: Titia Benders

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Name: Matthew Finkbeiner

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Name: David Strayer

Signed:

Additional Work

Listed are additional publications and presentations that have relevance to the thesis, but are not included in it:

Invited Presentations

1. Tillman, G (2016, August). Sequential Sampling Models of Perceptual Decision Making. Invited Talk presented for the Department of Linguistics, Macquarie University, Australia.

2. Tillman, G (2016, July). Advancing Cognitive Models of Perceptual Decision Making. Invited Talk presented for the Department of Psychology, Vanderbilt University, United States.

3. Tillman, G (2014, December). How Do Our Past Decisions Affect Our Present Decisions? Invited Talk presented for the University of Newcastle Cognitive Research Group, University of Newcastle, Australia.

Conference Presentations

1. Tillman, G. & Osth, A. (2016, February). Diffusion modeling reveals evidence for unequal variance signal detection models of the lexical decision task. Talk presented at the annual meeting of the Australian Mathematical Psychology Conference (AMPC), University of Tasmania, Australia.

2. Freeman, E., Tillman, G. & Osth, A. (2015, November). Recognition memory for familiar and unfamiliar items: Links between encoding and retrieval differences. Poster presented at the annual meeting of the Psychonomic Society, Chicago, United States.

3. Tillman, G. & Osth, A. (2015, November). Unequal Variance of Drift Rate Distributions in the Lexical Decision Task. Poster presented at the Computational Approaches to Cognition Symposium, Chicago, United States.

4. Tillman, G., Benders, T., Brown, S. D., & van Ravenzwaaij, D. (2015, November). Determining the Role of Spectral and Duration Cues in Vowel Perception. Talk presented at the annual meeting of the Configural Processing Consortium, Chicago, United States.

5. Tillman, G., Benders, T., Brown, S. D., & van Ravenzwaaij, D. (2015, April). Determining the Role of Spectral and Duration Cues in Vowel Perception. Talk presented at the annual meeting of the Australasian Society for Experimental Psychology, University of Sydney, Australia.

6. Tillman, G. & van Ravenzwaaij, D. (2015, February). Are Conclusions from Sequential Sampling Models Reliable? Talk presented at the annual meeting of the Australian Mathematical Psychology Conference (AMPC), Newcastle, Australia.

7. Tillman, G., Benders, T., Brown, S. D., & van Ravenzwaaij, D. (2014, November). A response time model on the role of spectral and duration cues in vowel perception. Poster presented at the annual meeting of the Psychonomic Society, Long Beach California, United States.

8. Tillman, G., Eidels, A., & Finkbeiner, M. (2014, July). Is Reading Mandatory? Reaching for Evidence in the Stroop Paradigm. Poster presented at the annual conference of the Cognitive Science Society, Quebec City, Canada.

9. Tillman, G., Eidels, A., & Finkbeiner, M. (2014, April). A Reach- To-Touch Investigation on the Nature of Reading in the Stroop Task. Talk presented at the annual meeting of the Australasian Society for Experimental Psychology, Brisbane, Australia.

10. Eidels, A., Williams, P., & Tillman, G. (2014, February). Serial-parallel model mimicry: the case for bimodality. Talk presented at the annual meeting of the Australian Mathematical Psychology Conference (AMPC), Canberra, Australia.

11. Tillman, G., Eidels, A., & Finkbeiner, M. (2013, December). Is Reading Mandatory? Reaching for Evidence in the Stroop Paradigm. Poster presented at the Priority Research Centre for Translational Neuroscience and Mental Health? Sixth Annual Postgraduate and Postdoctoral Conference, Newcastle, Australia.

Contents

Abstract

In this thesis I argue that cognitive psychologists can use the combination of sequential sampling models, Bayesian estimation methods, and model comparison via predictive accuracy to investigate underlying cognitive processes of perceptual decision-making. I show that sequential sampling models of simple and choice response time allow for researchers to analyze behavioral data and translate them into the constitute components of processing, such as speed of processing, response caution, and the time needed for perceptual encoding and overt motor responses. I use these methods and models to investigate underlying mental processes related to cognitive load, speech perception, and lexical decision-making. I also show that using different sequential sampling models to analyze the same data can lead researchers to draw different conclusions about cognitive processes, which serves as a caution for carelessly using these models. I also present a novel method that researchers can use to observe cognitive processes unfold online during perceptual decision-making tasks. I then discuss a promising collaboration emerging between researchers in the field of mathematical modeling and neuroscience.

For Lucy and Willow