AUSTRALASIAN MATHEMATICAL PSYCHOLOGY CONFERENCE 2017

BRISBANE, AUSTRALIA

Conference Overview

Tuesday, February 14th

10am - 12pm: AMPC Workshop

2pm - 5pm: AMPC Symposium

Wednesday, February 15th

9:10am - 4:30pm: Conference Day 1

4:30pm: Annual AMPC Cricket

Thursday, February 16th

9am - 4:30pm: Conference Day 2

6pm: Conference Dinner

Friday, February 17th

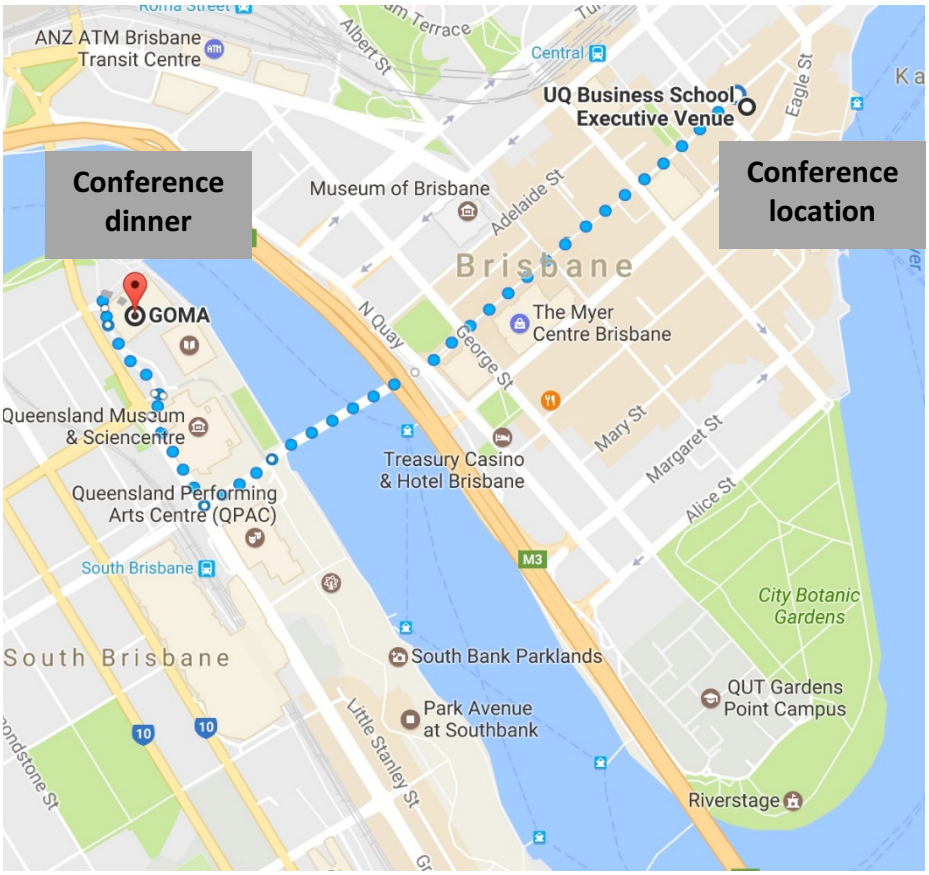
9am - 12:30pm: Conference Day 3

WELCOME

Welcome to Brisbane and the **2017 Australasian Mathematical Psychology Conference**. The conference is hosted by the University of Queensland, running from February 15-17th at the UQ Business School Executive Venue, which is located in the Brisbane CBD.

CONFERENCE DINNER

The conference dinner will be held on Thursday the 16th of February. The dinner will be held at the Queensland Gallery of Modern Art (GOMA), which is located just across the river from the CBD and is situated in the cultural precinct at South Bank. The dinner is approximately a 25 minute walk from the conference. Drinks and canapes will be available from 6 pm. Dinner will be served at 7 pm.



AMPC WORKSHOP

A free satellite workshop will be held on the morning of February 14th, at **UQ's St. Lucia campus** in the **Advanced Engineering Building** (Building 49, Room 301; see map below), and is scheduled to run from 10 am to 12 pm. There are no software or equipment requirements or prerequisites, and all are welcome to attend.

Personal Analytics and the Future of Psychological Research

Professor Simon Dennis, University of Newcastle

In the history of psychology, there have been three fundamental changes. The first of these was the realization that the scientific method could be applied to human behaviour. The second was the understanding that behaviour could be modelled using mathematics. The third was the development of techniques to examine the neural underpinnings of behaviour. We are on the cusp of the fourth major change. The ability to monitor human behaviour and context in the wild over periods of months and years will have a profound effect on the way we conduct our science.

In this workshop, I will describe the unforgettable.me experience sampling system. In addition to the unforgettable.me app which captures accelerometry, GPS, audio and images continuously, the system can stream data from 359 other sources, such as wearables, social media, financial services, appliances and cars. I will discuss machine learning and dynamic systems methods for analysing the large volumes of data that are collected. I will demonstrate the personal memory system that we are constructing and show how we are using the data to reimagine what an account of human memory might look like. I promise it will be an unforgettable talk.

AMPC SYMPOSIUM

We are offering a free satellite symposium on the afternoon of February 14th that will be focusing on the relationship between mathematical modeling and cognitive neuroscience. The symposium session will be held at **UQ's St. Lucia campus** in the **Advanced Engineering Building** (Building 49, Room 301, see map above), and is scheduled to run from 2-5 pm.

The goal of the symposium is to foster discussion about how the two areas might mutually benefit one another in terms of research collaboration, and become better integrated with regards to theory development.

The symposium is aimed at research higher degree students, postdocs, and early career researchers, though all are welcome to attend. We have planned a series of talks followed by a panel discussion:

Professor Michael Breakspear, QIMR Berghofer Medical Research Institute

Leonardo Gollo, Muhsin Karim, Justin A. Harris, John W. Morley, and Michael Breakspear

Nonlinear, hierarchical dynamics in prefrontal cortex modulate the precision of perceptual beliefs

Actions are shaped not only by the content of our percepts but also by our confidence in them. A decision that depends upon the comparison of two percepts rests upon the representation of stimulus properties and the precision with which each percept is held. To study the cortical representation of perceptual precision and decision making, we acquired functional imaging data acquired whilst participants performed two vibrotactile forced-choice discrimination tasks: a fast-slow judgement, and a same-different judgement. Whereas the first task only requires a comparison of the perceived vibrotactile frequencies, the second requires that the estimated difference between those frequencies be weighed against the precision of each perceptual representation. We report a constellation of cortical regions in rostral prefrontal cortex, dorsolateral prefrontal cortex and superior frontal gyrus associated with these operations. Dynamic causal modelling (DCM) of these data identified a nonlinear model, embodying a hierarchy of processing from the inferior parietal lobule through to the superior frontal gyrus. This model of effective connectivity outperformed competing models with serial and parallel interactions hence providing a unique insight into the hierarchical architecture underlying the representation and appraisal of perceptual belief and precision in prefrontal cortex

Dr Marta Garrido, Queensland Brain Institute

Modelling the interaction of attention and prediction errors

Predictive coding posits that the human brain continually monitors the environment for regularities and detects inconsistencies. It is unclear, however, what effect attention has on expectation processes, as there have been relatively few studies and the results of these have yielded contradictory findings. Here, we employed Bayesian model comparison to adjudicate between two alternative computational models. The *Opposition* model states that attention boosts neural responses equally to predicted and unpredicted stimuli, whereas the *Interaction* model assumes that attentional boosting of neural signals depends on the level of predictability. We designed a novel, audiospatial attention task that orthogonally manipulated attention and prediction by playing oddball

sequences in either the attended or unattended ear. We observed sensory prediction error responses, with electroencephalography, across all attentional manipulations. Crucially, posterior probability maps revealed that, overall, the *Opposition* model better explained scalp and source data, suggesting that attention boosts responses to predicted and unpredicted stimuli equally. Furthermore, Dynamic Causal Modelling (DCM) showed that these *Opposition* effects were expressed in plastic changes within the mismatch negativity network. Our findings provide empirical evidence for a computational model of the opposing interplay of attention and expectation in the brain.

Dr Bryan Paton, University of Newcastle

The Hierarchical Gaussian Filter in behaviour and brains

The Hierarchical Gaussian Filter (HGF) is a generic hierarchical Bayesian framework for understanding individual learning under uncertainty. Coupled Gaussian random walks, where the step size is determined by the next highest level in the hierarchy, model the evolution of hidden states of the world, the same hidden states that determine an agent's sensory input. Coupled to these perceptual models are response models that map the perceptual belief states to real world responses. Using a variational Bayes approach under a mean-field approximation, low computational cost single step updates of these models are possible, although Gaussian Process and MCMC are also possible. The HGF framework also implements a number of different perceptual models including Hidden Markov Models, Rescorla-Wagner, Pearce-Hall, Sutton, Armed Bandit and response models such as Log RT and Unit Square. Comparing different combinations of these models is relatively easy by using formal Bayesian model comparison techniques.

During this talk, I will show how the HGF framework can link changes in behaviour to brain states by combining it with EEG, fMRI, skin conductance, as well as physiologically informed approaches such as Dynamic Causal Models.

Associate Professor Paul Dux, The University of Queensland

Improvements in attention and decision-making following combined behavioural training and transcranial direct current stimulation: A combined brain stimulation & modelling study

In recent years there has been significant commercial interest in 'brain training' – massed or spaced practice on a small set of tasks to boost cognitive performance. Recently, researchers have combined cognitive training regimes with brain stimulation to try and maximise training benefits, leading to task-specific cognitive enhancement. It remains unclear, however, whether the performance gains afforded by such regimes can transfer to untrained tasks, or how training and stimulation affect the brain's latent information processing dynamics. To examine these issues, we applied transcranial direct current stimulation (tDCS) over the prefrontal cortex while participants undertook decision-making training over several days. Anodal, relative to cathodal/sham tDCS, increased performance gains from training. Critically, these gains were reliable for both trained and untrained tasks. The benefit of anodal tDCS occurred for left, but not right, prefrontal stimulation, and was absent for stimulation delivered without concurrent training. Modelling using the Linear Ballistic Accumulator framework revealed left anodal stimulation combined with training caused an increase in the brain's rate of evidence accumulation for both tasks. Thus tDCS applied during training has the potential to modulate training gains and give rise to transferable performance benefits for distinct cognitive operations through an increase in the rate at which the brain acquires information.

Professor Birte Forstmann, University of Amsterdam

Decision threshold dynamics in the human subcortex measured with ultra-high resolution magnetic resonance imaging

Deciding between multiple courses of action often entails an increasing need to do something as time passes - a sense of urgency. This notion of urgency is not incorporated in standard theories of speeded decision-making that assume information is accumulated until a critical fixed threshold is reached. In two experiments, we investigated the behavioral and neural evidence for an 'urgency signal' in humans. Experiment 1 found that as the duration of the decision-making process increased, participants made a choice based on less evidence for the selected option. Experiment 2 replicated this finding, and additionally found that variability in this effect across participants covaried with activation in striatum. These results are extended by using ultra-high resolution 7Telsa magnetic resonance imaging (MRI) to zoom in the spatio-temporal dynamics of the urgency signal in the striatum. We conclude that the striatum plays a more general role in the decision-making process than previously reported.

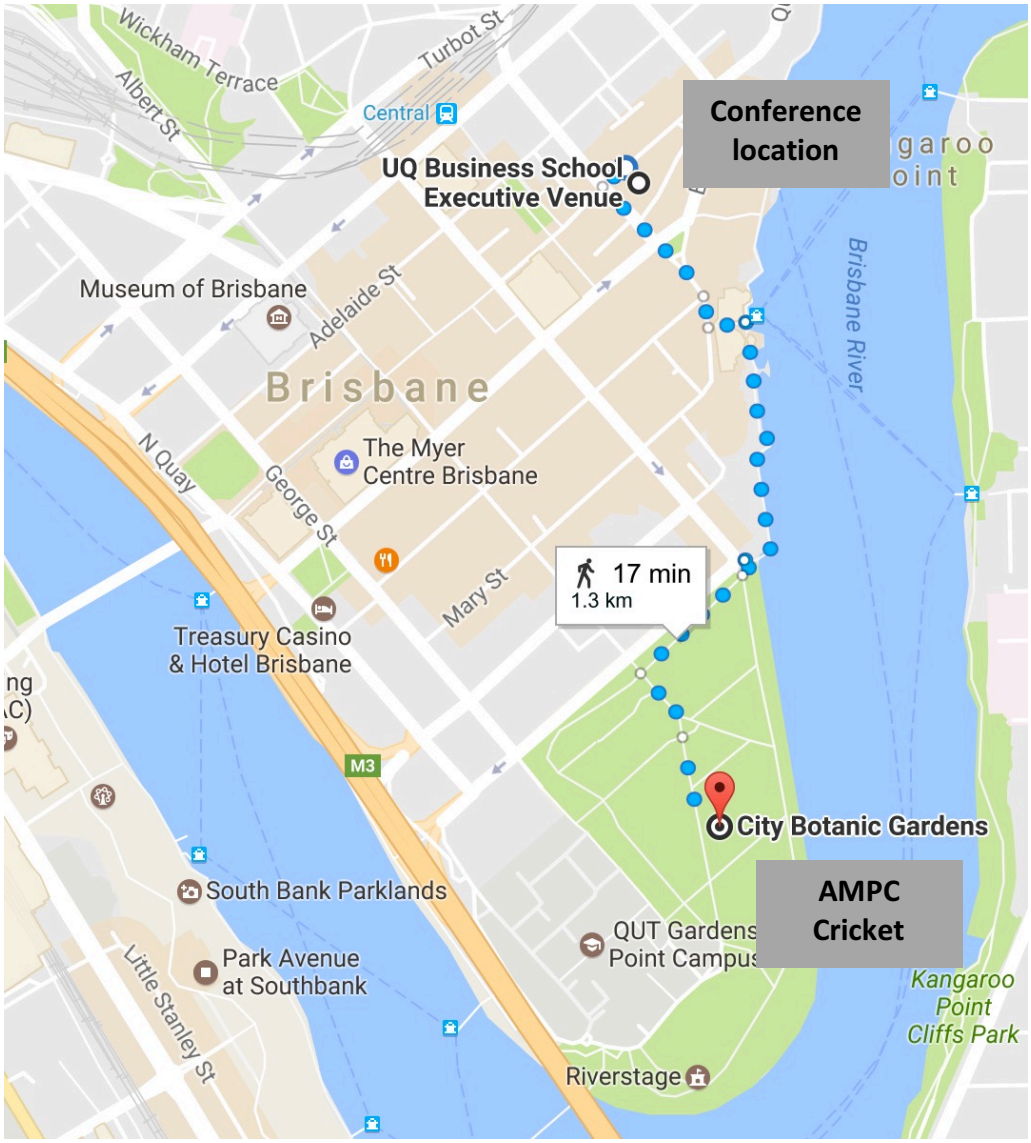
Professor Andrew Heathcote, University of Tasmania

A flexible and efficient hierarchical Bayesian approach to the exploration of individual differences in cognitive-model-based neuroscience.

Cognitive-model-based neuroscience provides powerful methods of finding the brain areas supporting latent psychological processes. One of these methods is to identify areas whose activation is associated with individual differences in the parameters of cognitive models. We describe how to apply this approach based on Bayesian hierarchical models that are estimated without reference to neural covariates. This enables efficient exploration of a rich sets of covariates without the computational difficulties associated with refitting the cognitive model. Our approach, based on methodology originating from educational surveys (e.g., Mislevy, 1991; Mislevy, Beaton, Kaplan, & Sheehan, 1992), avoids overconfidence that is associated with performing frequentist tests on posterior point estimates (Boehm, Marsman, Matzke, & Wagenmakers, submitted). We show how to extend this approach to takeaccount of uncertainty in generalizing from a sample of participants to the population (Ly, Marsman, & Wagenmakers, 2015), providing an assessment of whether findings will generalize to new samples. We apply our methods to Forstmann et al.'s (2008) fMRI study of the relationship between activation in the Basal Ganglia and pre-SMA and threshold setting in the LBA model (Brown & Heathcote, 2008). We compare their individual maximumlikelihood estimates to both individual and hierarchical Bayesian estimates obtained using Differential Evolution Markov chain Monte Carlo sampling (Turner, Sederberg, Brown, & Steyvers, 2013).

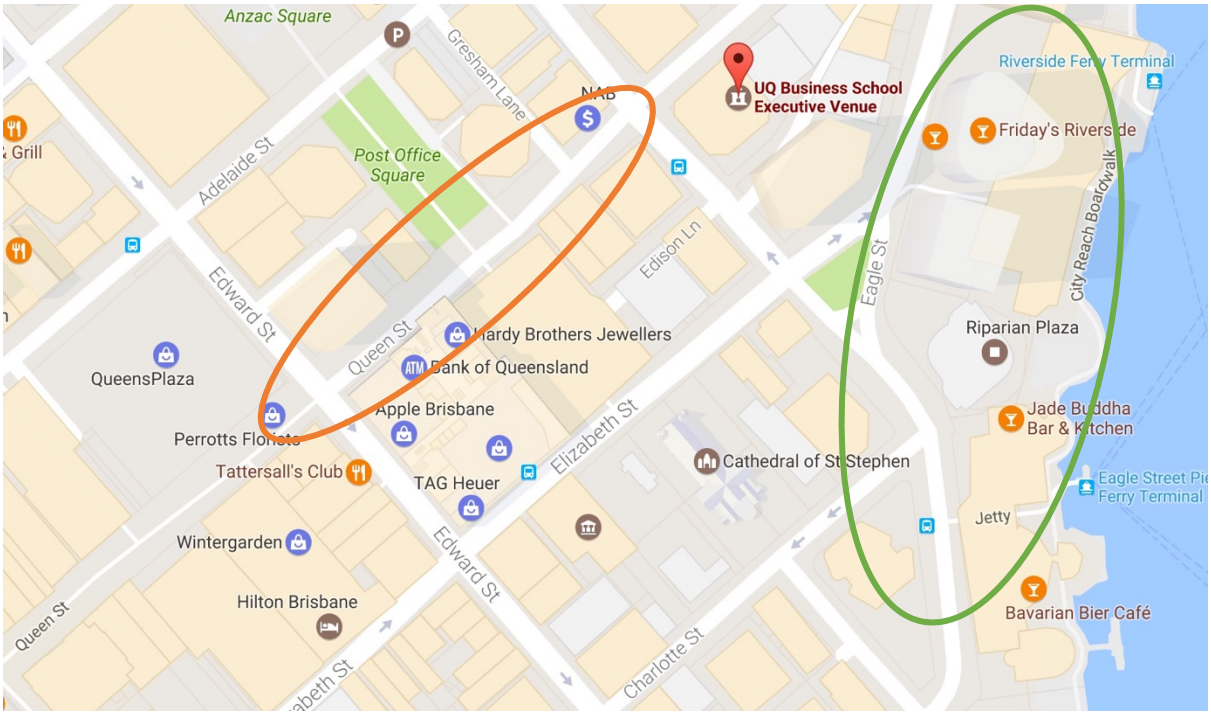
AMPC CRICKET

We will have the traditional cricket game at the end of Conference Day 1 (Wednesday, February 15th). At the end of the Conference schedule (4:30pm) we will make our way to the Brisbane City Botanic Gardens. This is approximately a 17 minute walk along the Brisbane River.



LUNCH & COFFEE LOCATIONS

There are several lunch and coffee venues around the UQ Business School Executive Venue. You could go for a walk along Queen Street (orange ellipse), or go riverside for a number of venues (green ellipse).



CONFERENCE TIMETABLE

WEDNESDAY 15TH

Time	Event	Authors
9:10 - 9:20	AMPC Welcome	Dave Sewell
	SESSION 1 CHAIR: David Sewell	
9:20 - 9:40	Modeling Decision Processes on a Continuous Scale	Roger Ratcliff
9:40 - 10:00	Recovering the Between-Trial Variability Parameters of the Drift-diffusion Model Using the Hierarchical Bayesian Method with Differential Evolution Markov Chain Monte Carlo Sampler	Yi-Shin Lin and Andrew Heathcote
10:00 - 10:20	Using response time models to understand unfamiliar face matching	Carolyn Semmler, Andrew Hendrickson, Anna Ma-Wyatt, and Rebecca Heyer
10:20 - 10:40	Modeling decisions among psychologically related alternatives	Peter D. Kvam
10:40 - 11:10	**Coffee**	
	SESSION 2 CHAIR: Philip Smith	
11:10 - 11:30	Pop-out visual search depends critically on display density	Dragan Rangelov, Hermann J. Müller, Thomas Töllner, and Michael Zehetleitner
11:30 - 11:50	The Power Law of Visual Working Memory Characterizes Attention Engagement	Philip Smith, Elaine Corbett, Simon Lilburn, and Søren Kyllingsbæk
11:50 - 12:10	Processing Conflicting Information (Mary Shelley's version)	Ami Eidels and Daniel Little
12:10 - 12:30	Effects of a hierarchy of timescales in the brain: Structure-dynamics interplay, and tuning curves in response to brain stimulation	Leonardo L. Gollo, Luca Cocchi, James Roberts, and Michael Breakspear
12:30 - 2:00	**Lunch**	
	SESSION 3 CHAIR: Daniel Little	
2:00 - 2:10	Opportunities and challenges of eFourier analysis applications	Erin Walsh, Marnie Shaw, Kaarin Anstey, and Nicolas Cherbuin
2:10 - 2:20	The processing architecture and information capacity of detecting spatially separate luminance changes	Anthea G. Blunden, Dylan Hammond, Piers Howe, and Daniel Little

2:20 - 2:30	Attentional Modulation of Processing Architecture: A Systems Factorial Technology Approach	Sarah Moneer and Daniel R. Little
2:30 - 2:40	Decision Making Components of Attentional Deficits in Schizophrenia	Laura Wall, Juanita Todd, and Scott Brown
2:40 - 2:50	A test of the holistic processing of composite faces using Systems Factorial Technology and Logical-Rule Models	Xue Jun Cheng, Callum McCarthy, Tony Wang, Thomas Palmeri, and Daniel Little
2:50 - 3:00	Correlated evidence accumulator models	Angus Reynolds, Andrew Heathcote, and Barbara Holland
3:00 - 3:30	**Coffee**	
	SESSION 4 CHAIR: Tim Ballard	
3:30 - 3:40	Further tests of sequential effects in a modified Garner task using separable dimensions	Deborah Lin, and Daniel Little
3:40 - 3:50	Generalization in Multiple Cue Judgment	Arthur Kary, Ben R. Newell, and Chris Donkin
3:50 - 4:00	The role of prediction error and confidence in sequential decision making	Christina Van Heer, David Sewell, Robert Hester, and Philip Smith
4:00 - 4:10	Item Response Model with CDF-Quantile Family Likelihoods	Yiyun Shou and Michael Smithson
4:10 - 4:20	Attribute Bias in a Calibrated Context Effect Task	Shi Xian Liew, Piers Howe, and Daniel Little
4:20 - 4:30	How Do I Choose Between Effect Size Indices? A review of the classification methods used to guide selection of effect size indices.	Sheri Kim
4:30	**Cricket**	

THURSDAY 16TH

Time	Event	Authors
	SESSION 5 CHAIR: Adam Osth	
9:00 - 9:20	A hierarchical Bayesian model of memory for when	Simon Dennis, Vishnu Sreekumar, Nathan Evans, and Paul Garrett
9:20 - 9:40	Modeling the dynamics of recognition memory testing with a combined model of retrieval and decision making	Adam Osth, Anna Jansson, Simon Dennis, and Andrew Heathcote
9:40 - 10:00	Item-Response Learning in Memory Search	Rui Cao, Robert Nosofsky, and Richard Shiffrin
10:00 - 10:20	Proactive and reactive control in prospective memory	Luke Strickland, Shayne Loft, Roger Remington, and Andrew Heathcote
10:20 - 10:40	Adaptive decision-making in simulated air-traffic control	Russell J. Boag, Luke Strickland, Andrew Heathcote, and Shayne Loft

10:40 - 11:10	**Coffee**	
	SESSION 6 CHAIR: Dan Navarro	
11:10 - 11:30	When extremists win: Cultural transmission via iterated learning when priors are heterogeneous	Daniel Navarro, Amy Perfors, Arthur Kary, Scott Brown, and Chris Donkin
11:30 - 11:50	How to ask people about sentence acceptability: different task assumptions, sources of variability, and sample sizes	Steven Langsford, Lauren Kennedy, Andrew Hendrickson, Amy Perfors, and Daniel Navarro
11:50 - 12:10	An evaluation of internal and external language models account of semantic relatedness	Simon De Deyne, Amy Perfors and Dan Navarro
12:10 - 12:30	Modeling Word Learning through Context	Hyungwook Yim, Vladimir M. Sloutsky, Xin Yao, and Simon J. Dennis
12:30 - 2:00	**Lunch**	
	SESSION 7 CHAIR: Chris Donkin	
2:00 - 2:20	The role of coupling and copulas in modeling multisensory integration	Hans Colonius and Adele Diederich
2:20 - 2:40	Cognitive models of distracted task performance	Guy E. Hawkins, Matthias Mittner, Andrew Heathcote, and Birte U. Forstmann
2:40 - 3:00	Bridge sampling: A simple yet powerful method for comparing complex cognitive models	Dora Matzke, Quentin F. Gronau, and Eric-Jan Wagenmakers
3:00 - 3:30	**Coffee**	
	SESSION 8 CHAIR: Ami Eidels	
3:30 - 3:40	A New Approach to Understanding Systems of Estimation	Paul Garrett, David Landy, Joseph Houpt, and Ami Eidels
3:40 - 3:50	Investigating the processing of dual-cue memory intersection problems	Zach Howard, Bianca Belevski, Ami Eidels, and Simon Dennis
3:50 - 4:00	The role of reward and reward uncertainty in episodic memory	Alice Mason, Casimir Ludwig, Paul Howard-Jones, and Simon Farrell
4:00 - 4:10	Is the probability estimation bias in decisions from experience a regression towards the mean effect?	Aba Szollosi, Garston Liang, Emmanouil Konstantinidis, Christopher Donkin, and Ben Newell
4:10 - 4:20	Priors, informative cues and ambiguity aversion	Lauren A. Kennedy, Amy Perfors, and Daniel J. Navarro
4:20 - 4:30	Decision making about vaccinations	Andrew Hendrickson and Amy Perfors
6:00	**Dinner**	

FRIDAY 17TH

Time	Event	Authors
	SESSION 9 CHAIR: Ben Newell	
9:00 - 9:20	Tracking Eyes to Change Minds?	Ben Newell and Mike Le Pelley
9:20 - 9:40	Context effects in preferences for partitioned stimuli	Simon Farrell
9:40 - 10:00	Aiming to choose correctly or to choose wisely? Understanding the optimality-accuracy trade-off	Thomas Garcia and Sébastien Massoni
10:00 - 10:20	Comparing rule-based and sequential sampling models of deferred decision making	Jared M. Hotaling, Jörg Rieskamp, and Sebastian Gluth
10:20 - 10:40	Exploring the decision dynamics of risky intertemporal choice: Towards a rule-based and dimension-wise computational model	Emmanouil Konstantinidis, Don van Ravenzwaaij, and Ben R. Newell
10:40 - 11:10	**Coffee**	
	SESSION 10 CHAIR: Mike Smithson	
11:10 - 11:30	Are verbal short-term memories all or none?	Chris Donkin, Robert Taylor, and Mike Le Pelley
11:30 - 11:50	Distributions for Modelling Imprecise Probabilities	Michael Smithson
11:50 - 12:10	Do we know what we don't know?	Nathan Weber, James D. Sauer, and Adeline Goh
12:10 - 12:30	Models of simultaneous and sequential lineups.	John C. Dunn, Carolyn Semmler, and Matthew Kaesler
12:30 - 2:00	**Business & Close.**	

CONFERENCE ABSTRACTS

THE PROCESSING ARCHITECTURE AND INFORMATION CAPACITY OF DETECTING SPATIALLY SEPARATE LUMINANCE CHANGES

Anthea G. Blunden, Dylan Hammond, Piers Howe, and Daniel Little
The University of Melbourne

Systems Factorial Technology (SFT) is non-parametric tool for diagnosing information processing architecture (i.e., whether processing is serial, parallel, or coactive), information processing capacity (i.e., whether capacity is limited or unlimited), and associated stopping rules. SFT has commonly been used in the context of perceptual categorisation. In the present talk, we apply SFT to the basic question of diagnosing the processing architecture during change detection memory tasks with different perceptual stimuli. We investigated processing architecture when participants detected changes in two spatially separated luminance discs of opposite polarity (one black and one white disk). We found that change detection could plausibly be either parallel or coactive with limited capacity. Further, differences in processing architecture may be dependent on the overall direction of the luminance change, i.e., whether luminance changes in both discs occur in the same direction (mean shift) or in opposite directions (range shift).

ADAPTIVE DECISION-MAKING IN SIMULATED AIR-TRAFFIC CONTROL

Russell J. Boag[1], Luke Strickland[2], Andrew Heathcote [2], and Shayne Loft[1]
1. University of Western Australia; 2. University of Tasmania

This project applies Bayesian Linear Ballistic Accumulator (LBA) models of decision-making to a complex and dynamic air-traffic control (ATC) task. We aim to explain how individuals adapt decision-making strategies in response to changes in time pressure, relative response importance, and the presence of concurrent prospective memory (PM) demands.

The ATC task involved classifying pairs of moving aircraft as either 'in-conflict' or 'not in-conflict'. On some trials aircraft also contained a rare PM cue which required execution of an atypical PM response. These decisions require the integration of multiple information sources (e.g., relative distance, airspeed) on a dynamic display while balancing several competing task demands (e.g., time pressure, PM demands). Moreover, decisions typically unfolded over relatively long time-scales (up to 10 seconds). Initial work suggests that models of simple choice such as the LBA can account for decision-making performance in these more complex, longer time-scale, and less controlled applied settings.

Preliminary modelling shows evidence of both proactive and reactive adaptations to the decision-making environment. In terms of proactive adaptation, response thresholds were higher under PM load. This suggests individuals proactively raise their response thresholds when required to hold additional PM intentions. Conversely, response thresholds were lower under increased time pressure. This suggests individuals proactively lower their thresholds under high time pressure to facilitate faster responding.

In terms of reactive adaptation, drift rates for on-going task stimuli were lower when they also contained a PM target than when the same stimuli did not contain a PM target. For example, the drift rate for the in-conflict accumulator was lower for in-conflict PM targets compared to in-conflict

aircraft that were not PM targets. The same pattern was observed for non-conflict aircraft. We suggest that the presence of the PM stimulus inhibits the evidence accumulation process for the congruent on-going task response.

ITEM-RESPONSE LEARNING IN MEMORY SEARCH

Rui Cao, Robert Nosofsky, and Richard Shiffrin
Indiana University

A fundamental distinction in tasks of memory search is whether items receive varied mappings (targets and distractors switch roles across trials) or consistent mappings (targets and distractors never switch roles). Classic studies have demonstrated the development of automaticity under consistent-mapping (CM) conditions, whereas varied-mapping (VM) performance remains capacity limited even after extensive practice. Many popular theories assume that the dramatic performance improvement under CM conditions arises due to item-response learning, whereas in VM conditions observers rely on overall familiarity or short-term memory for the current list. In the present study, we manipulated the frequency of individual stimuli in CM and VM conditions, and formalized both item-response learning and familiarity-based mechanisms within the framework of an evidence-accumulation model of memory-search performance. The familiarity-based model predicted biases toward responding "old" to high-frequency items in both the CM and VM conditions. The item-response learning model predicted performance advantages for high-frequency old and new items in the CM condition, but performance disadvantages for the high-frequency old and new items in the VM condition. The qualitative pattern of results and formal modeling provided evidence for item-response learning in both CM and VM conditions.

A TEST OF THE HOLISTIC PROCESSING OF COMPOSITE FACES USING SYSTEMS FACTORIAL TECHNOLOGY AND LOGICAL-RULE MODELS

Xue Jun Cheng[1], Callum McCarthy, Tony Wang[2], Thomas Palmeri[3], and Daniel Little[1]
1. The University of Melbourne, 2. Brown University, 3. Vanderbilt University

The composite face paradigm used often in the face-processing literature suggests that upright faces are processed holistically (i.e., represented according to their whole and not their constituent parts) and inverted faces are not. Holistic processing in this paradigm is inferred from decreased recognition performance for upright, aligned composite faces compared to inverted and misaligned faces. However, the composite face task does not necessarily address the nature of holism in the way that the term "holism" is sometimes defined computationally. In a categorization task, we use the logical-rule models and Systems Factorial Technology to examine whether composite faces are processed through pooling top and bottom face halves into a single processing channel (i.e., coactive processing) which is one mechanistic definition of holistic processing. By operationalising holistic processing as the pooling of features into a single decision process in our task, we can distinguish it from other processing models such as a failure of selective attention (another common definition of holistic processing) which can arise even when top and bottom components of the composite faces are processed in serial or parallel. We found that performance is best explained by a mixture of serial and parallel processing architectures across all four upright and inverted, aligned and misaligned face conditions. The results indicate multichannel, featural processing of composite faces which is inconsistent with the notion of coactivity. These results indicate multi-channel, featural processing of composite faces which is inconsistent with the notion of coactivity. we limit our conclusions to the processing of composite faces.

THE ROLE OF COUPLING AND COPULAS IN MODELING MULTISENSORY INTEGRATION

Hans Colonius[1] and Adele Diederich[2]
1. Oldenburg University, 2. Jacobs University Bremen

Coupling means the construction of a joint distribution of two or more (previously unrelated) random variables, whereas copulas are functions that relate multivariate distribution functions to their one-dimensional margins and that permit separating assumptions about multivariate dependence from specifying the marginal distributions. Multisensory modeling strives to understand how information from the unisensory channels (e.g., visual, acoustic) is merged into a multisensory product. We demonstrate with several examples, from both behavioral and neurophysiological paradigms, how coupling and copulas can inform models of multisensory processing.

AN EVALUATION OF INTERNAL AND EXTERNAL LANGUAGE MODELS ACCOUNT OF SEMANTIC RELATEDNESS

Simon De Deyne[1], Amy Perfors[1], and Dan Navarro[2]
1. *University of Adelaide*, 2. *University of New South Wales*

Over the past few years, semantic vector models that learn to predict a word from its context or vice versa like *word2vec* (Mikolov et al., 2013) have become influential in computational linguistics due to their superior ability to predict word relatedness compared to count-based word co-occurrence models. These language prediction models are becoming increasingly influential in psychology as well as they can account for a wide range of findings in semantic cognition and word processing in general (Mandera, Keuleers, & Brysbaert, 2016). This work also suggests these models might learn word meaning in a way that resembles human learning. If so, this would mean that the structure encoded in external language models accurately reflects our mental representations and the puzzle of lexical semantic is mostly solved.

To evaluate these claims, we propose to contrast two types of models that are epistemically distinct. E-language models, like word2vec, treat language as an "external" object consisting of the all utterances made in a speech-community. In contrast to these E-language models, I-language model treats language as the body of knowledge residing in the brains of its speakers. If E-language models are indeed sufficiently accurate to capture representations resembling human mental representations, we expect them to perform similarly to I-language models across tasks that tap into how humans process meaning.

Using relatedness judgments, we compared recent E-language models with an I-language model derived from word association data and found that the latter consistently outperform current state-of-the art text-based E-language models, often with a large margin. These results are not just a performance improvement; they also have implications for our understanding of how distributional knowledge is used by people. To explain why this is the case, we will briefly discuss very recent work that suggests I-language models accurately capture multimodal (visual and emotional) representations which might be difficult to derive from external language alone.

A HIERARCHICAL BAYESIAN MODEL OF MEMORY FOR WHEN

Simon Dennis[1,2], Vishnu Sreekumar[2], Nathan Evans[1], and Paul Garrett[1]
1. University of Newcastle, 2. Unforgettable Technologies Inc, 3. National Institutes of Health

Participants wore a smartphone, which collected GPS, audio, accelerometry and image data, in a pouch around their necks for a period of two weeks. After a retention interval of one week, they were asked to judge the specific day on which each of a selection of images was taken. To account for people's judgements, we proposed a mixture model of four processes - uniform guessing, a signal detection process based on decaying memory strength, a week confusion process, and a event confusion processes in which the sensor streams were used to calculate the similarity of events. A model selection exercise testing all possible subsets of the processes favoured a model that included only the event confusion model. GPS similarities were found to be the most significant predictors, followed by audio and accelerometry similarities and then image similarities.

ARE VERBAL SHORT-TERM MEMORIES ALL OR NONE?

Chris Donkin, Robert Taylor, and Mike Le Pelley
University of New South Wales, Australia

Most theories of verbal short-term memory assume a continuous memory strength, instead of an all-or-none representation. We use a ranking task to investigate this notion. In a set of preliminary, exploratory studies, we find that short-term representations of words appear to be all-or-none, while nonwords appear to be continuous. In this talk, we also outline our plan for a pre-registered study, and ask for feedback on the details of this proposal, including our planned analysis and the stopping rule for data collection.

MODELS OF SIMULTANEOUS AND SEQUENTIAL LINEUPS.

John C. Dunn, Carolyn Semmler, and Matthew Kaesler
The University of Adelaide.

Eyewitness research has focused on whether sequential or simultaneous lineups lead greater identification accuracy. In a simultaneous lineup, the witness is shown the entire lineup and decides if any is the culprit and, if so, whom. In a sequential lineup, the witness is shown each member sequentially and, following each presentation, decides if they are the culprit or not. Initial findings by Lindsay and Wells (1985) showed that the sequential procedure produced a marked reduction in false identification rate coupled with a slightreduction in correct identification rate compared to the simultaneous procedure. Subsequent studies have produced conflicting results and it is not clear if there is a systematic difference between the two lineups and, if so, whether this pertains to discriminability, response criterion, or both. To attempt to address these questions, we developed two signal detection models for simultaneous and sequential lineups, respectively, and used them to re-analyse the data base of 44 cases collected by Palmer and Brewer (2012). Our results confirm the original conclusion reached by these authors – sequential lineups have no effect on discriminability but induce a more conservative decision criterion. We demonstrate through model simulations how this is consistent with a rational strategy.

PROCESSING CONFLICTING INFORMATION (MARY SHELLEY'S VERSION)

Ami Eidels[1] and Daniel Little[2]
1. University of Newcastle, 2. University of Melbourne

Conflicting sources of information could slow down our responses and cause errors. In the lab, a classic example of the detrimental effects of conflicting information is the Stroop effect. Classifying the print colour of a colour word takes more time and is more prone to errors when the colour and word dimensions are in conflict (e.g., the word GREEN printed in red) than when they match (RED in red). We show that researchers can take advantage of this conflict-driven slowdown in their endeavour to uncover the architecture (serial, parallel) of the cognitive system. We develop a new measure, the *Conflict Contrast Function* (CCF), which contrasts response-time distributions from conditions that vary in the strength of conflict information, and show that serial, parallel, and coactive systems each predict a unique CCF signature. We apply the new measure to previously collected data sets (Eidels et al, 2010; Little et al, 2011, 2013) and extend previous inference. Most interestingly, we demonstrate a radical shift in processing mode with and without conflicting information: matching colour and word are processed in parallel, whereas conflicting sources of information seem to be processed is serial.

CONTEXT EFFECTS IN PREFERENCES FOR PARTITIONED STIMULI

Simon Farrell
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Previous work (e.g., Mellers & Cooke, 1996) has shown that people's preferences for multi-attribute stimuli in riskless decision-making are sensitive to the range of each of the attributes. When choosing between alternatives or rating multi-attribute judgements, changes in attributes with a narrow range produce greater changes in judgement and choice than changes in attributes with a wide range. Such effects can be understood as following from the incommensurate nature of attributes measured on different scales, and can be accounted for by Parducci's Range-Frequency Theory (1965). Here we examined whether similar effects are observed when attributes are measured on a common scale but are partitioned by the presentation format (where other research has shown such partitioning---e.g., breaking total cost into item cost and shipping---affects purchasing intentions: Morwitz et al., 1998). Participants were presented with pairs of values (e.g., two monetary amounts making up a total amount won in a hypothetical prize draw), and asked to rate their satisfaction with each pair. We fit a variety of models representing different strategies for assessing and combining values from the individual attributes. While there was some heterogeneity between individuals in behaviour, in a cover story with little background context outside the lab people behaved as though they assessed each attribute independently (using ranking as per Parducci's theory) and then aggregated the individual attribute ratings. One consequence of this result was non-monotonicity in people's ratings as a function of total value: people sometimes preferred less money to more money.

AIMING TO CHOOSE CORRECTLY OR TO CHOOSE WISELY? UNDERSTANDING THE OPTIMALITY-ACCURACY TRADE-OFF

Thomas Garcia[1,2] and Sébastien Massoni[2]
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When making a decision under uncertainty, decision makers aim to take the optimal decision. In general, an accurate decision is optimal. However, in many real life situations asymmetrical stakes

induce a divergence between optimality and accuracy (e.g. in medical decision-making). Previous empirical studies show that decision makers behave "as if" they are maximizing a combination of expected reward and accuracy. But, the origins of this optimality-accuracy trade-off are yet to be understood. This question has been tackled through two experiments of perceptual decision with asymmetric payoffs allowing for the use of Signal Detection Theory as a normative benchmark. The first experiment confirms previous findings by highlighting the existence of the optimality-accuracy trade-off with a leading role of accuracy. The second experiment explains this trade-off by the importance putted on the fact of being right.

A NEW APPROACH TO UNDERSTANDING SYSTEMS OF ESTIMATION

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Large groups of items are typically quantified through a process of estimation. Similarly, the comparison of two large groups is achieved through a system of estimation. In their study, Halberda, Sires and Feigenson (2006) suggested that this system may be parallel (able to estimate two groups simultaneously) and unlimited in process capacity (unaffected by group size). While their findings are compelling, the use of traditional analysis techniques such as mean RT and accuracy have precluded direct assessment of these properties. We introduce a new approach for measuring the cognitive properties underlying systems of estimation using Systems Factorial Technology (SFT). Using previously collected data, we will show how SFT can be successfully applied to the study of numerical cognition and Systems of Estimation.

EFFECTS OF A HIERARCHY OF TIMESCALES IN THE BRAIN: STRUCTURE-DYNAMICS INTERPLAY, AND TUNING CURVES IN RESPONSE TO BRAIN STIMULATION

Leonardo L. Gollo, Luca Cocchi, James Roberts, and Michael Breakspear
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From slow social interaction to fast perception, the brain must cope with events whose duration spans several orders of magnitude. It has been proposed that a hierarchy of timescales may play an important role to solve this conundrum (Kiebel, Daunizeau, & Friston, 2008). Using large-scale brain simulations, we show that a hierarchy of timescales recapitulating the structural hierarchy of the brain naturally emerges. Highly connected hub regions are more stable and evolve in a slower timescale than poorly connected peripheral regions. The enhanced stability of hubs is consistent with their involvement in emotions and mood dynamics, and the larger flexibility of peripheral regions is consistent with their role in fast sensory perception (Gollo, Zalesky, Hutchison, van den Heuvel, & Breakspear, 2015). Hence, the existence of a hierarchy of timescales constitutes a fundamental link between brain structure and dynamics. This structure-dynamics relationship also shapes changes in brain dynamics following local stimulation. We find that the same stimulation protocol may cause opposite effects in functional connectivity if one stimulated region is a hub and another is peripheral (Cocchi et al., 2016). These contrary effects are part of a continuous tuning curve that represents how the different brain regions respond to stimulation depending on their hierarchical position. These results indicate that the dynamical heterogeneity observed in the brain can be summarized as a hierarchy of timescales following a topological axis linking core and peripheral regions of the connectome.

COGNITIVE MODELS OF DISTRACTED TASK PERFORMANCE

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Participants frequently experience distraction and/or mind wandering while completing experimental psychology tasks. Despite its frequency, distraction is rarely considered to be sufficiently central to task performance so as to warrant explicit inclusion in cognitive models. Here, we examined performance in the sustained attention to respond task (SART) - a go-nogo task with a very high proportion of go stimuli - which permeates the field of mind wandering research, where task-unrelated thoughts and distraction are the core features of study. We identified three critical response time patterns in SART data that cannot be explained with standard choice response time models: very fast responses, a 'soft' leading to the response time distribution, and a much faster distribution of error response times than correct response times. To account for these trends in data, we propose a simple addition to standard accumulator models that can account for the three patterns present in SART data: a race between a go accumulator, a nogo accumulator, and a 'failed-decision' accumulator. The failed-decision accumulator assumes that a (variable) amount of time may pass during a trial after which the participant simply 'gives up' on the decision process and provides a response; a response that is not the result of a stimulus-driven decision. The failed-decision accumulator introduces an implicit timing component to the accumulator model framework that allows it to provide a good account of all patterns in the SART choice and response time data. It also provides insight into subjective reports of off-task thoughts during task completion. We conclude by discussing how the model might also provide a simple replacement for urgency signal / collapsing decision boundary modifications that have been recently proposed for sequential sampling models.

DECISION MAKING ABOUT VACCINATIONS

Andrew Hendrickson and Amy Perfors
University of Adelaide

Decisions about vaccinations are an example of an abstract class of decision problems with very rare but very extreme outcomes. Known as "Black Swans", these problems are particularly hard for humans to grapple with, and have been studied mainly in the context of financial investments by experts or after-the-fact explanations of rare events (Taleb, 2005). The decision to vaccinate or not is a particularly interesting example of a Black Swan scenario, because outcomes in both directions are rare and extreme: side effects of vaccinations are much less likely than is believed by some, but they do exist; and, conversely, the chance of a non-vaccinated child becoming ill from an infectious disease is larger than is commonly believed. This is internationally recognized as a growing problem as an increasing proportion of parents are hesitant about immunization for their children. However, little is still understood about the reasons that "vaccine hesitancy" is increasing (Shrivastava, 2016). In this work we present preliminary results and analyses that challenge the conventional thinking of what interventions are likely to succeed in reversing the trend toward vaccination hesitancy.

COMPARING RULE-BASED AND SEQUENTIAL SAMPLING MODELS OF DEFERRED DECISION MAKING

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Many important choices require that the decision maker collect evidence to better inform a choice between two or more uncertain alternatives. We conducted two deferred decision making (DDM) experiments in which participants acted as physicians diagnosing patients during an outbreak of two diseases. Participants could purchase up to twenty independent blood tests, each providing evidence in favor of one of two mutually exclusive diagnoses. Due to the possibility of test errors, participants purchased multiple tests, until they were confident which disease was present. The goal of the task was to make accurate diagnoses, while minimizing testing costs.

Our results show sensitivity to sampling costs—participants purchased more tests when sampling costs were low—and risk—participants purchased more tests when rewards and punishments were large. We also tested the ability of several models to predict when participants would stop testing and make a terminal choice. A stochastic version of the error cost stopping rule (ECSR), first proposed by Busemeyer and Rapoport (1988), performed reasonably well, however, an alternative sequential sampling model (SSM) outperformed the relatively inflexible ECSR. According to the SSM, individuals independently accumulate information in favor of each response (*Disease A*, *Disease B*, and *purchase another test*) based on the set of observed test results. Importantly, the SSM uses collapsing decision thresholds to represent the fact that individuals require less evidence to make a diagnosis as the number of tests increases. These findings lay the groundwork for further investigation into the cognitive mechanisms underlying DDM.

INVESTIGATING THE PROCESSING OF DUAL-CUE MEMORY INTERSECTION PROBLEMS

Zach Howard, Bianca Belevski, Ami Eidels, and Simon Dennis
The University of Newcastle, Australia

How do we solve memory problems that require more than one cue to be considered? For example, try to remember which movie was created by Disney and was about the Greek mythology. Intuitively we might expect that the cues [Disney, Greek Mythology] would be processed together, in parallel. This would seemingly allow the solution, the 'intersection' of the cues (Hercules, in this example), to be readily identified. However, some recent investigations have concluded that participants actually only consider one cue at a time. This distinction between serial (one-at-a-time) and parallel processing of memory cues could have important implications for our theoretical understanding of human memory, and problem solving more generally. Our project aims to remedy some methodological concerns from previous work to facilitate our understanding of the process that leads to the identification of an intersection. We present two studies, one in which participants are queried about a potential intersection, and a second in which they must generate the intersection of two cues for themselves. Using a novel application of the powerful Systems Factorial Technology, we present preliminary evidence that most participants use both cues in parallel to solve an intersection problem. We also find some evidence that the proportion of subjects using parallel processing changes between tasks, which presents a possible avenue for reconciling the conflicting evidence in the literature.

GENERALIZATION IN MULTIPLE CUE JUDGMENT

Arthur Kary, Ben R. Newell, and Chris Donkin
University of New South Wales

Making continuous judgments on the basis of evidence from multiple cues is a common part of everyday life. For example, we may judge the ripeness of a piece of fruit by observing its color, its firmness and its smell. But what kinds of mental representations underlie these judgments? When the environment involves linear combinations of cues, it has been argued that individuals are able to integrate representations of the cue weights to form a judgment. However, when the environment involves more complex combinations of cues, exemplar processes are thought to be involved. The vast majority of evidence accumulated in this debate has been derived from supervised learning tasks. Instead, we employ a generalization design in which people are presented with all stimuli at once and have to fill in the missing values for some of the stimuli. We compare preliminary data from our task to the body of literature using supervised learning tasks.

PRIORS, INFORMATIVE CUES AND AMBIGUITY AVERSION

Lauren A. Kennedy[1], Amy Perfors[1], and Daniel J. Navarro[2]
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Ambiguity aversion, or the preference for options with known rather than unknown probabilities is a robust finding within the decision making literature (see Camerer & Weber, 1992, for a review). There are some suggestions this averseness is due to participants inferring differences in the prior distribution for the ambiguous option (Güney & Newell, 2015). In this study we investigated the relationship between prior distributions and experienced information cues on decision making and participants judgements of underlying distribution. We used three different prior cues; positive (suggesting a positive underlying distributional cue), neutral (no distributional cue) and negative (suggesting a negative underlying distributional cue) and five different information cues, varying both the bias of the information and the degree of ambiguity. Whilst we found that both prior and information manipulations had the expected impact for participants' judgements of underlying distributions, they only impacted the decisions participants made some of the time. There were also interesting interactions between the two for decision and not judgements. We discuss the implications for this.

HOW DO I CHOOSE BETWEEN EFFECT SIZE INDICES? A REVIEW OF THE CLASSIFICATION METHODS USED TO GUIDE SELECTION OF EFFECT SIZE INDICES.

Sheri Kim
Australian National University

The Replication Crisis has brought about a revived discussion on the need to improve the research methods used in psychological research. Along with this discussion, there has been a re-emphasis on the benefits of using (calculating, reporting, interpreting) effect sizes. Over the years, there has been an increasing number of effect size indices (ESIs) suggested for use in psychological research. One way that methodology researchers attempt to gain and communicate clarity about ESIs is to classify the indices into groups. Some of these classifications also provide guidance for selecting ESIs, although not all classifications were developed for this purpose. I will review the ways in which ESIs have been classified, and highlight the inconsistencies between different methods of classification. I will then suggest an alternate method for selecting ESIs, and explore its benefits and disadvantages.

EXPLORING THE DECISION DYNAMICS OF RISKY INTERTEMPORAL CHOICE: TOWARDS A RULE-BASED AND DIMENSION-WISE COMPUTATIONAL MODEL

Emmanouil Konstantinidis[1], Don van Ravenzwaaij[2], and Ben R. Newell[1]
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Research on risky intertemporal choice has assumed a utility-based integrative approach for risky and delayed prospects, according to which, prospects are evaluated independently from each other and all information (payoff, probability, and delay) is integrated into the evaluation process. These models do not often provide descriptions for the processing steps of information acquisition and do not account for the use of simplifying strategies or rules in decision-making. Using a process-tracing experimental design, we examined the order in which information is acquired, transitions between information items, and the use of strategies (e.g., alternative-wise vs dimension-wise evaluation). Overall, the process-tracing data suggest that people use simple rules and dimensional comparisons when evaluating prospects that are both delayed and probabilistic. We used these findings to identify core observations and assumptions about decision-making with delayed and probabilistic rewards, and to inform the development of a computational process model for intertemporal risky choice (PRITCH: Process Risky InterTemporal Choice).

MODELING DECISIONS AMONG PSYCHOLOGICALLY RELATED ALTERNATIVES

Peter D. Kvam
Michigan State University

Models of the decision process have traditionally focused on the case where choices are made between a pair of alternatives. More recent approaches to modeling decisions among multiple alternatives are frequently based on these binary models, but this work has shown that the psychological relations between alternatives have a significant impact on the speed and allotment of responses. In this talk, I present an approach to modeling decisions between arbitrarily many choice alternatives (including selections on a continuum) that naturally incorporates these psychological relations. I examine some of its predictions using a perceptual experiment where the number of choice options and the similarity relations between them are systematically manipulated. The experiment examines how the physical (hue) relations among colors map onto psychological relations, and how similarity ratings can be used to construct a spatial representation of the alternatives. The study shows how representation models like multidimensional scaling can be integrated with decision models to form a more complete account of how people make choices among many alternatives.

HOW TO ASK PEOPLE ABOUT SENTENCE ACCEPTABILITY: DIFFERENT TASK ASSUMPTIONS, SOURCES OF VARIABILITY, AND SAMPLE SIZES

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This project evaluates a range of measures for sentence acceptability in terms of accuracy, variability, and reliability. These measures include Likert scales, two versions of forced-choice judgments, magnitude estimation, and a novel measure based on Thurstonian approaches in psychophysics. Likert scales, targeted forced choice judgments, and magnitude estimation are all

widely used instruments for eliciting acceptability judgments, and previous work has examined the statistical power of these methods and their degree of agreement with expert linguists. This project contributes to this ongoing work by examining two novel methods alongside these more established ones on a common set of items, and by considering both within-participant reliability and between-participant reliability at varying sample sizes. Contrasting diverse measures in parallel shows how sensitive the results are to assumptions imposed by each. We find that despite their drastically different assumptions, Likert ratings and Thurstonian acceptability estimates are highly consistent, suggesting that plausible objections to the specific assumptions made by each are not limiting in practice. Contrasting between and within participant reliability shows the extent to which the different tasks are sensitive to individual differences and item neighborhood effects, which contribute to between-participant variability only. We find that the different measures are differently vulnerable to these sources of variation, with magnitude estimation particularly sensitive. Contrasting varying sample sizes shows the relative efficiency of each method. We find that targeted forced-choice comparisons have extremely high power, but are also more likely than other methods to include sign errors among the differences identified. Taken together, these results help show not just that these methods for measuring sentence acceptability are different, but how and why they are different.

ATTRIBUTE BIAS IN A CALIBRATED CONTEXT EFFECT TASK

Shi Xian Liew, Piers Howe, and Daniel Little
The University of Melbourne

Recent studies have suggested that context effects in multi-alternative choice – observations where relative choice probabilities between options are dependent on the choice set – are highly susceptible to particular biases such as preferred attributes or extremeness aversion. We present a novel context effect paradigm that involves a calibration of the probability of gambles to each individual's indifference curve, followed by observing their choice probabilities in a ternary-choice context effect task. Despite participating in a calibration phase, participants continued to exhibit attribute biases when tested for context effects. Our results build on and support past research that demonstrate meaningful qualitative differences between different groups within a sample. We model the observed data and briefly discuss its implications.

RECOVERING THE BETWEEN-TRIAL VARIABILITY PARAMETERS OF THE DRIFT-DIFFUSION MODEL USING THE HIERARCHICAL BAYESIAN METHOD WITH DIFFERENTIAL EVOLUTION MARKOV CHAIN MONTE CARLO SAMPLER

Yi-Shin Lin[1] and Andrew Heathcote[1,2]
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Between-trial variability parameters in the diffusion decision model (DDM; Ratcliff, 1978) are difficult to estimate, as shown in recent parameter recovery studies (Lerche & Voss, 2016; Lerche, Voss, & Nagler, 2016; Ratcliff & Childers, 2015), with Lerche and co-authors concluding that, for smaller samples, it is best of fix rather than estimate variability parameters even when their true values are unknown. These finding poses questions regarding the necessity of using the full DDM to fit data, and regarding the minimal trial numbers required for parameter recovery. We investigate these questions for hierarchical Bayesian (HB) estimation methods, which have claimed to offer advantages over earlier methods (e.g., Ratcliff & Tuerlinckx, 2002; Heathcote, Brown, & Mewhort, 2002). However, several available HB methods for the DDM (Wiecki, Sofer, & Frank, 2013; Vandekerckhove, Tuerlinckx, & Lee, 2011; Wabersich & Vandekerckhove, 2014) lack the ability to fit between-trial variability parameters. We implemented HB methods that can estimate the full DDM,

and conducted two simulation studies to investigate three questions: (1) Are variability parameters recoverable? (2) Do HB methods help parameter recovery with small trial and participant numbers? (3) Are other parameter estimates distorted when the fitted DDM ignores real differences in variability parameters between conditions? We found that it is possible to recover variability parameters, that our HB method using differential evolution Markov Chain Monte Carlo (Braak, 2006; Turner, Sederberg, Brown, & Steyvers, 2013) can recover parameters with small trial and participant numbers, and that fitting a model that miss-specifies variability parameters can compromise general parameter recovery.

FURTHER TESTS OF SEQUENTIAL EFFECTS IN A MODIFIED GARNER TASK USING SEPARABLE DIMENSIONS

Deborah Lin, and Daniel Little
The University of Melbourne

In the study of perceptual categorization, a key distinction between *integral* and *separable* dimensions is often made. *Integral* dimensions, such as chroma and hue of a colour, are often highly unanalyzable and difficult to attend in isolation, while *separable* dimensions, such as saturation and size, are highly analysable and easy to selectively attend to. In the classic Garner (1974) speeded-classification paradigm, a standard result is that response times are roughly invariant to variation on the irrelevant dimension for separable dimensions, but are relatively faster when correlated variation on the irrelevant dimension is introduced (i.e., correlated-facilitation) and slower when there is instead orthogonal variation on the irrelevant dimension (i.e., filtering- interference) for integral dimensions. Little, Wang, and Nosofsky (2016) showed that when trial-by-trial data is analysed, significant and consistent pattern of sequential effects were found in an extended Garner paradigm using integral-dimension stimuli. The present study seeks to investigate whether these pronounced sequential effects extend to separable-dimension stimuli. Two experiments using different sets of separable-dimension stimuli were conducted for generalizability. The results indicate that similar patterns of sequential effects are present in perceptual categorization of separable-dimension stimuli, but an effect of a change in the irrelevant dimension from the preceding stimuli was not found. The estimated model parameters for a hierarchical Bayesian implementation of a sequence-sensitive exemplar model also suggest fewer representational differences between control, correlated, and filtering tasks for separable-dimension stimuli. The findings of the present study provide a more complete account of perceptual categorization and add to the growing body of literature on the prevalence and critical implications of strong sequential effects in cognitive tasks.

THE ROLE OF REWARD AND REWARD UNCERTAINTY IN EPISODIC MEMORY

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Declarative memory has been found to be sensitive to reward related changes in the environment. The reward signal can be broken down into information regarding the expected value of the reward, reward uncertainty (entropy) and the prediction error. Previous research has established a link between reward signals and episodic memory: high (vs low) reward values enhance declarative memory. fMRI and single cell recording studies have furthermore suggested that high uncertainty activates the reward system. This talk will present research examining whether reward uncertainty can promote memory in the same manner as reward value. Participants completed a motivated word learning task in which the probability of receiving a fixed reward varied from 0.1 to 0.9 in increments

of 0.2. Rewards were dependent upon memory performance in a delayed recognition test. Uncertainty did not predict memory performance. While this might be explained by a lack of response to the reward stimuli, it was found that memory was related reward outcome value. This adds to other findings from our lab that provide consistent evidence against an effect of reward uncertainty on declarative memory.

BRIDGE SAMPLING: A SIMPLE YET POWERFUL METHOD FOR COMPARING COMPLEX COGNITIVE MODELS

Dora Matzke, Quentin F. Gronau, and Eric-Jan Wagenmakers
University of Amsterdam

Cognitive modelers are often faced with the challenge of comparing the descriptive accuracy of a limited set of non-linear models. The candidate models often vary in complexity and are equipped with a large number of parameters, especially when the models are implemented in a hierarchical framework. The principled Bayesian solution to these model comparison problems is to compute the ratio of the marginal likelihoods of the competing models, a quantity known as the Bayes factor. The Bayes factor quantifies the change from the prior odds to the posterior odds of the models brought about by the data and allows researchers to evaluate evidence for the models on a continuous scale. In the context of cognitive models, however, the marginal likelihood is typically analytically intractable and must be approximated using numerical methods. Here we present bridge sampling (Meng & Wong, 1996), a powerful yet straightforward simulation-based approach that enables the accurate computation of the marginal likelihood of complex cognitive models. We first illustrate bridge sampling using a hierarchical multinomial processing tree model of memory retrieval. We then discuss the generalization of the procedure to the Linear Ballistic Accumulator model, and outline the strengths and weaknesses of our approach.

ATTENTIONAL MODULATION OF PROCESSING ARCHITECTURE: A SYSTEMS FACTORIAL TECHNOLOGY APPROACH

Sarah Moneer and Daniel R. Little
The University of Melbourne

Attention is required to select task-relevant information for further processing and suppress other irrelevant, and perhaps conflicting information in the visual scene. Several models have been proposed to account for the distribution of attention in the visual field (e.g. space-based vs. object-based); however, these models make assumptions about how the attended information is processed that do not account for differences in the properties of stimulus dimensions and the time course of information processing. Evidence from our previous studies has suggested that the physical distance between dimensions that are perceptually separable affects processing architecture, and hence decision times, in a categorization task. Further, classification response times (RT) for stimuli in which these separable dimensions overlap were best accounted for by a model that allows for a mixture of serial and parallel processing strategies, which could be explained by fluctuations in the allocation of attention across trials. In the present study, we manipulate the object affiliation (i.e., same object or different objects) of a pair of visual features (saturation and orientation) and the separation between them to investigate how the distribution of attention in the visual field modulates processing architecture. Differential Evolution Markov Chain Monte Carlo models and Systems Factorial Technology analyses were used to determine processing strategies. Evidence for parallel processing was found in all conditions, including one in which features were presented in separate objects at an

extreme separation value. These findings support the spotlight model of the allocation of visual attention.

WHEN EXTREMISTS WIN: CULTURAL TRANSMISSION VIA ITERATED LEARNING WHEN PRIORS ARE HETEROGENEOUS

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How does the process of information transmission affect the cultural or linguistic products that emerge out of that process? This question is often studied experimentally and computationally via iterated learning, in which participants learn from previous participants in a chain. Much research in this area builds on mathematical analyses suggesting that iterated learning chains converge to people's priors (Griffiths & Kalish, 2007) or exaggerate weak priors in a population (Kirby, Dowman, & Griffiths, 2007). Here we present three simulation studies and one experiment demonstrating that when the population of learners is heterogeneous, rather than all sharing the same prior, these prior results do not hold. Rather, the behaviour of the chain is systematically distorted by the learners with the most extreme biases, resulting in population-level outcomes that do not reflect the behaviour of any individuals within the population. We discuss implications for the use of iterated learning as a methodological tool as well as for the processes that might have shaped cultural and linguistic products in the real world.

TRACKING EYES TO CHANGE MINDS?

Ben Newell and Mike Le Pelley
The University of New South Wales

Can decisions be biased via passive monitoring of eye-gaze? We examined this question using a simple perceptual discrimination task (Experiment 1) and a more complex moral decision-making task (Experiment 2). Information about the location of participants' gaze at particular time-points in a decision trial was used to prompt responses. When there was no objective perceptual information available to decision-makers, the timing of the prompt had a small, but detectable effect on choice (Experiment 1). However, this small effect did not scale up to more complex decisions (Experiment 2). These results are consistent with idea that participants' choices are reflected in their eye-gaze, but do *not* support the recent bold claim of a causal link wherein the timing of a gaze-contingent response-prompt influences complex choices. The results will be discussed in the context of evidence accumulation models that attempt to document how eye-gaze patterns translate into preference for options.

MODELING THE DYNAMICS OF RECOGNITION MEMORY TESTING WITH A COMBINED MODEL OF RETRIEVAL AND DECISION MAKING

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Abstract: A robust finding in recognition memory is the observation that performance declines monotonically across test trials. Despite the prevalence of this result, there is a lack of consensus on the mechanism responsible for the decline. Three hypotheses have been put forward: 1.) interference

is caused by the learning of test items 2.) the test items cause a shift in the context representation used to cue memory and 3.) participants change their speed-accuracy thresholds through the course of testing. We implemented all three possibilities in a combined model of recognition memory and decision making, which inherits the memory retrieval elements of the Osth and Dennis (2015) model and uses the diffusion decision model (Ratcliff, 1978) to generate choice and response times. We applied the model to four datasets that represent three challenges in the literature on testing effects in recognition memory: 1.) the finding that the number of test items plays a larger role in determining performance than the number of studied items, 2.) the finding that performance decreases less for strong items than weak items in pure lists but not in mixed lists, and 3.) the finding that lexical decision trials interspersed between recognition test trials do not impact performance. The model provided an excellent account of choice and response time data and analysis of the resulting parameter estimates suggests that item interference plays a minor role in explaining the effects of recognition testing relative to context drift, which showed very strong correlations with the size of the testing effect. Changes in speed-accuracy thresholds did not show a consistent tendency either upward or downward through the course of testing, but were demonstrated to show a substantial role in moderating the size of the testing effect. These results are consistent with prior work showing a weak role for item interference in recognition memory and other results demonstrating that retrieval is a strong cause of context change in episodic memory.

POP-OUT VISUAL SEARCH DEPENDS CRITICALLY ON DISPLAY DENSITY

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Spotting a black dog in a flock of sheep is an effortless task, as if the image of the dog popped out against the background. Investigating which visual stimuli do and do not pop out is essential for characterising early vision. Pop-out search implies that the target (the dog) is always the first item selected, no matter how many distractors (the sheep) are presented. Increasing evidence, however, indicates that search is not entirely independent of display density even for pop-out targets: search is slower with sparse (few distractors) than with dense displays (many distractors). Despite its significance, the cause of this anomaly remains unclear. Using a mixture-distribution modelling approach together with electrophysiological measures, we investigated several mechanisms that could slow down search for pop-out targets. Consistent with the assumption that pop-out targets frequently fail to pop out in sparse displays, we observed greater variability of search duration for sparse displays relative to dense. Computational modelling of the response time distributions also supported the view that pop-out targets fail to pop out in sparse displays. Finally, the best-fitting model parameters correlated significantly with electrophysiological markers of spatial attention. Our findings strongly question the classical assumption that pop-out search operates independently of the number and spatial distribution of the distractors. Rather, the density of the distractors critically influences whether or not a stimulus pops out. These results call for new, more reliable measures of pop-out search and potentially a re-interpretation of studies that used relatively sparse displays.

MODELING DECISION PROCESSES ON A CONTINUOUS SCALE

Roger Ratcliff
The Ohio State University

I present a model for perceptual decision making for stimuli and responses in continuous space on lines, circles, and planes. The experiments use a range of stimulus types, including perceptual,

symbolic, dynamic, and static. Participants were asked to make eye movements, mouse movements, or finger movements to, for example, the brightest part of a display or the color on a wheel surrounding a central stimulus that matches the central stimulus. The models are diffusion processes on lines and planes. In the models, evidence from a stimulus drives the noisy decision process which accumulates evidence over time to a criterion at which point a response is initiated. Noise is represented as a continuous Gaussian process or Gaussian random field. The model produces predictions for the full distributions of response times and choice probabilities and fits to data for choice probability, RT distributions, and choice proportion and RT across the stimulus space are presented.

CORRELATED EVIDENCE ACCUMULATOR MODELS

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Accumulator models for rapid choice usually treat the finishing times of each accumulator as being independent within-trial. This assumption is made for mathematical convenience, as the likelihood for an independent race is easy to compute, but is of questionable plausibility. We discuss some motivations for violations of independence (e.g., global fluctuations in attention likely cause positively correlated inputs). We give the likelihood function for a two-choice correlated Log-Normal Race (Heathcote and Love, 2012) model and examine parameter recovery using Maximum Likelihood Estimation and Bayesian methods.

USING RESPONSE TIME MODELS TO UNDERSTAND UNFAMILIAR FACE MATCHING

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Response time has long been a central variable in the investigation of decision processes. Despite this – its value in applied contexts such as unfamiliar face matching has been largely overlooked. Models of response time may be of particular value in understanding expertise in face matching, as they define parameters that drive superior performance. We fit several RT models to a data set that includes both experienced individuals from several Australian government agencies that use face matching in their work and to a novice sample. We also explore the relationships between the parameters estimated from the data set and key individual difference tests often used in the unfamiliar face matching literature. The differences between the experienced and the novice individuals were minimal, however there are some constraints of the data set that limit the conclusions that we can draw. We discuss the value of formal models to applied settings and hope to encourage ongoing application of formal models in applied research.

ITEM RESPONSE MODEL WITH CDF-QUANTILE FAMILY LIKELIHOODS

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Item response theory (IRT) was originally developed for modelling candidates' abilities from a set of test items. The IRT framework is useful for understanding the properties of test items and capturing the underlying latent ability trait. In this paper, we consider the IRT models for items with doubly bounded scales such those in probability judgments and event forecasting tasks. Recent work has

employed beta distributed likelihood (Noel & Dauvier, 2007) and probit-normal likelihood (Merkle et al., 2016) models. We introduce the IRT model using CDF-quantile family likelihood models, which could be potentially more flexible in capturing various shapes in responses. Using geopolitical forecasts data, we elucidate how the CDF-quantile models can be promising for probability judgements data, when compared to the beta and probit-normal likelihoods.

THE POWER LAW OF VISUAL WORKING MEMORY CHARACTERIZES ATTENTION ENGAGEMENT

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The quality or precision of stimulus representations in visual working memory can be characterized by a power law, which states that precision decreases as a power of the number of items in memory, with an exponent whose magnitude typically varies in the range 0.5 to 0.75 when precision is measured in standard deviation units. We show that the magnitude of the exponent is an index of the attentional demands of memory formation. We report five visual working memory experiments with tasks that varied in their attentional demands and show that the magnitude of the exponent increases systematically with the attentional demands of the task. Recall accuracy in the experiments was well described by a model that views visual working memory as a population of noisy evidence samples that can be allocated flexibly under attentional control. The magnitude of the exponent indexes the degree to which attention allocates resources to items in memory unequally rather than equally.

DISTRIBUTIONS FOR MODELLING IMPRECISE PROBABILITIES

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There is little guidance in the statistical literature for modelling judged probability intervals or lower-upper probability subjective assignments, or for assessing the coherence of such assignments. Coherent lower-upper probability judgements have a form where the lower probability is $\underline{p}_i = W\left(p_i, \theta\right)$, and the "conjugate" upper probability is $\overline{p}_i = 1 - W\left(1 - p_i, \theta\right)$, for some function *W* monotonic in p_i and θ a parameter governing the difference between the lower and upper probabilities. Even if we specify the function, how do we fit a distribution to the p_i and estimate θ? It turns out that 2-parameter cdf-quantile distributions (Smithson & Shou, 2016) offer a solution, with θ as a third parameter and the inverse of *W* incorporated into the cdf argument. Define the cdf function $G\left(W^{-1}\left(x,\theta\right),\mu,\sigma\right) = F\left[U\left(H^{-1}\left(W^{-1}\left(x,\theta\right)\right),\mu,\sigma\right)\right]$, where *F* and *H* are CDFs satisfying certain symmetry conditions, and *U* monotonically transforms its argument to the support for *F*. Then it can be shown that $1 - G\left(W^{-1}\left(1-x,\theta\right),-\mu,\sigma\right) = G\left(1 - W^{-1}\left(1-x,\theta\right),\mu,\sigma\right).$

For members of the cdf-quantile family with appropriate *W*, the quantile functions that are inverses of cdfs $G\left(W^{-1}\left(x,\theta\right),\mu,\sigma\right)$ and $G\left(1-W^{-1}\left(1-x,\theta\right),\mu,\sigma\right)$ behave as conjugate lower and upper probabilities. As with their 2-parameter counterparts, these distributions are tractable and amenable to maximum likelihood and Bayesian MCMC estimation methods. This presentation elaborates these concepts and presents an example of fitting conjugate distribution pairs to real lower and upper probability judgement data.

PROACTIVE AND REACTIVE CONTROL IN PROSPECTIVE MEMORY

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Event-Based Prospective Memory (PM) requires remembering to perform intended deferred actions when particular stimuli or events are encountered in the future (Einstein & McDaniel, 1990). PM tasks often require deviating from routine decisions. In the current study, we present an inaugural computational model of the entire human decision processes underlying PM performance. The specific model we fit is a three accumulator linear ballistic accumulator (LBA; Brown & Heathcote, 2008). We conducted two experiments. In Experiment 1, we manipulated the importance of the PM task. In Experiment 2, we manipulated PM target focality. Target focality refers whether the ongoing task directs attention to the features of PM targets processed at encoding (Einstein et al., 2005). Both proactive and reactive control (Braver, 2012) were evident over routine decision processing. Routine responding was proactively controlled with increased thresholds. There was also reactive control on PM target trials, with PM accumulation increasing and routine response accumulation decreasing. Increased reactive control over routine decisions was critical to account for the effects of both PM importance and PM focality.

IS THE PROBABILITY ESTIMATION BIAS IN DECISIONS FROM EXPERIENCE A REGRESSION TOWARDS THE MEAN EFFECT?

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When making uncertain decisions from experience, people's choices suggest that they underweight small probabilities. Intriguingly, when they are also asked to provide a probability estimate for such rare events, they tend to overestimate them compared to their objective probability of occurrence. A suggested explanation for this overestimation bias is that it is a regression towards the mean effect. This explanation assumes that people can infer the correct probability through repeated experience, but this inference is subject to random error. Therefore, the overestimation is the result of the imbalance in the response scale, which makes it easier for people to err towards the higher estimates.

To investigate this explanation, we incentivized people to be more accurate in their probability estimation. If the overestimation bias was a regression towards the mean effect, we expected that people's judgments would become more accurate as the incentives would reduce the error. In line with this explanation, the results showed that the mean estimates became more accurate when the estimation task was incentivized. However, detailed analyses of the data revealed that people's probability estimates were not normally distributed around the objective probability - an assumption of the regression towards the mean effect. Instead, the responses were consistent with a belief in a dynamic rather than a static decision environment. The apparent improvement was due, in part, to an increase in stating a 0 probability of the consecutive occurrence of a rare event. Such tendencies pulled the mean estimates closer to the objective value. These results show that the overestimation bias is not a regression towards the mean effect and thus present a challenge for explanations and models of the simultaneous underweighting and overestimation of rare events in decisions from experience.

THE ROLE OF PREDICTION ERROR AND CONFIDENCE IN SEQUENTIAL DECISION MAKING

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The role of confidence in decision making has received much attention but substantially less emphasis has been placed on how confidence may influence the learning process. A representation of confidence may be required for learning in probabilistic environments, where an agent cannot perfectly predict outcomes because of the inherent uncertainty in the task. Supporting this, confidence has been shown to track the likelihood of change points (contingency change) in the environment, and the prediction error in sequential decisions, suggesting an internal representation of confidence may be used to guide learning. However, these two things are typically conflated in previous work. Thus, we sought to investigate how observers used prediction errors and confidence to update their estimates. We used a sequential decision making task, where subjects learnt about numbers sampled from a gaussian distribution (c.f. Nassar et al., 2010) by making predictions about the outcome of the sampling process, and learning from feedback about the sample estimate. We found that subjects estimates could be accounted for by a simple additive learning model, where subjects use the previous error in prediction to update their estimates. I discuss models of how confidence and prediction error may influence the process of prediction updating.

DECISION MAKING COMPONENTS OF ATTENTIONAL DEFICITS IN SCHIZOPHRENIA

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University of Newcastle

There is consistent evidence that people with schizophrenia show deficits across a number of different tasks used to measure attention. Most of these tasks require participants to make multiple, repeated, speeded decisions and are therefore vulnerable to effects of speed accuracy trade-offs, bias, motor speed and more. Slower performance of people with schizophrenia on such tasks may therefore be explained by more than simply impaired attention.

People with schizophrenia and healthy undergraduates completed a conjunction search task. The schizophrenia group performed significantly slower than controls for all set sizes. The two groups' results were then modelled separately using the Linear Ballistic Accumulator to decompose performance into bias, caution, motor speed and processing speed. A few possible models were fit to the data and a combination of visual inspection and WAIC was used to determine the best fit for each group.

OPPORTUNITIES AND CHALLENGES OF EFOURIER ANALYSIS APPLICATIONS

Erin Walsh, Marnie Shaw, Kaarin Anstey, and Nicolas Cherbuin
Australian National University

The corpus callosum is the large bundle of neural fibres that connects the left and right cerebral hemispheres in the brains of placental mammals. Because corpus callosum shape provides insight into topological distribution of inter-hemispheric connectivity, its global shape is a point of interest in both the human and animal neuroimaging community. Previously, we examined the human corpus callosum and established that elliptical Fourier analysis is a reliable and robust tool for the extraction of global shape, particularly when used in combination with principal components analysis. Moving from benchmarking to application, this talk will highlight analytical peculiarities of applying this method to neural structures in humans and animals (e.g. the 'horseshoe' effect in shape space;

statistical artefact or genuine reflection of morphometric characteristic?), and discuss avenues for extension (e.g. simultaneous inclusion of multiple global shapes in a single analysis).

DO WE KNOW WHAT WE DON'T KNOW?

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Despite evidence of their usefulness, little is known of the processes underpinning *don't know* responses in complex memory tasks such as lineups. We investigated three related issues of theoretical and applied importance: 1. What factors drive the rate of *don't know* responses? 2. Are participants aware of the influence of these factors? 3. If so, can this awareness provide useful information in the applied context? In two parallel experiments, we used a face recognition mini-lineup paradigm with computer-generated 3D face models. In one experiment, we manipulated the stimulus exposure duration during study and, in the other, we manipulated the similarity of the faces in test array. Participants were tested with pairs of stimuli (a foil with a *guilty* – old – or *innocent* – new) and were asked to (i) select the studied face, (ii) indicate that a studied face was not present in the array, or (iii) if unsure, respond *don't know*. *Don't know* responses were followed with a probe to determine the reason for the response by selecting: (i) faces are too similar, (ii) memory is too poor, or (iii) other. We used Bayesian hierarchical conditional logistic models to analyse the data. They revealed a substantial increase in *don't know* responses with increasing face similarity and, despite a clear impact on willingness to choose a face, a marginal impact of exposure duration on *don't knows*. The *don't know* clarifications indicate that participants could correctly attribute the cause of these changes. Finally, although don't know responses were no more likely for guilty versus innocent suspects, when separated by participant's reported reason, some *don't know* responses were informative about likely guilt. Thus, our results provide some support for Cark's (2003) WITNESS model of lineup decision making and suggest that *don't know* clarifications are a promising avenue of investigation to easily and cheaply improve the quality of lineup evidence.

MODELING WORD LEARNING THROUGH CONTEXT

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Studies and computational models of word learning have mostly focused on ostension (i.e., explicit naming of a visually present referent or candidate referents) as a mechanism to map a word to its meaning. However, not all words could be learned through ostension either because they are abstract and have no referent, or because the referents are not present when the word is uttered. We propose an associative account that explains word learning through context and how the pattern of learning changes through development. The model is implemented as a neural network model that learns two types of associations (i.e., syntagmatic associations and paradigmatic associations) from a natural corpus. A syntagmatic association refers to the association among words that co-occur in an utterance such as *furry* and *dog* as in "*the furry dog*". A paradigmatic association refers to words that have a similar context such as *dog* and *cat* as in '*the furry dog*' and '*the furry cat*'. The paradigmatic associations are second order associations and could be built up on the basis of the syntagmatic associations, and therefore would come online after the syntagmatic associations. We argue that this delay in learning the paradigmatic associations could explain the developmental changes in word learning. The model is supported by 16 experiments across two age groups, and naturally explains the developmental pattern as a function of experience.