July 18th - 21st
Québec City, Canada

MathPsych 2014

47th Annual Meeting of the Society
for Mathematical Psychology

www.mathpsych.org

UNIVERSITÉ LAVAL

uOttawa

Bienvenue à Québec!

Dear Colleagues,

We are happy to welcome you to the 47th Annual Meeting of the *Society for Mathematical Psychology*. This year, we have keynote addresses from **Horace Barlow**, **Richard Sutton** and **Wolf Vanpaemel**, the 2013 winner of the William K. Estes Early Career Award. There are three invited symposia with a total of 18 talks and one workshop. Also, there is 71 contributed talks, and 28 posters. As a pre-conference event, we have the professional development symposium of the **Women of Mathematical Psychology** presenting "Negotiations: Data and advice and a closing conference by **Richard M. Shiffrin**.

We would like to acknowledge the financial support of the Université d'Ottawa and the Université Laval. Their support made an important contribution to many aspects of this year's conference. We would also like to acknowledge the tremendous efforts made by the students volunters.

Finally, this year's conference features Québec city. We hope you will enjoy your stay and take time to visit the oldest city in North America.

Best regards,

The organizing committee: Denis Cousineau, Sylvain Chartier, Sébastien Hélie, François Vachon.

Program Booklet Credits

General content:	2014 Organizing Committee
Abstracts:	Their respective authors
LaTeX-code:	Denis Cousineau, Bradley Harding
LaTeX-code based on an earlier version by:	Timo Kluck, Infty Advies (www.infty.nl) & MLC Inc.

Contents

General Information

Location

The conference will be held in the Hotel Hilton Québec, 1100 René Lévesque Est, Québec, Québec, Canada G1R 4P3, www.hiltonquebec.com. All major events of the conference will take place on the first floor, except for the Welcome reception (see below). The list of conference rooms is as follows:

- **Grande place** (Welcome Area): Registration, information desk (see map)
- **Palais**: Keynote talks, plenary meetings, business meeting
- **Port-Neuf & Ste-Foy**: Symposia, parallel sessions
- **Courville & Montmorency**: Parallel sessions
- **Kent**: Poster session
- **Lauzon**: SMP meeting and JMP editor's meeting

Welcome Reception

The Welcome Reception will be on Friday, July 18th, in the *Des plaines* room, on the top floor, from 5:30 p.m. to 8:00 p.m. Refreshments will be provided.

Conference Office

The registration desk can be found in the Grande Place room, 1st floor. Opening hours: 8:00 a.m. to 6:00 p.m. On the opening day (Friday, July 18th), the conference office will open at 4:00 p.m. and close at 8:00 p.m.

Internet Access

Internet access will be provided via the Hotel's WiFi network. You will find access information on a card enclosed in your name tag.

Lunch & Coffee breaks

Lunch is not provided by the conference. Refreshments and snacks will be offered during selected coffee breaks.

Conference Dinner

The conference dinner will be held in the *Le Parlementaire*. Located in the Parliament Building, Le Parlementaire is a magnificent beaux arts dining room that offers a menu worthy of the most refined palates. From 1917 to 1968, Le Parlementaire was a gathering place reserved for MNAs, but for over 40 years now, its doors have been open to the public.

Places to Eat

Québec city has literally thousands of restaurants. Many of them are located on St-Jean street (two corners north of the hotel), on Grande Allée (one corner south of the Hotel) and in the old city, within the medieval walls. A map is found two pages below with a suggested few locations.

Co-located Conferences

All the following co-located conferences are held in the Hilton Hotel or in the adjacent conference center.

COGSCI 2014
Annual Meeting of the Cognitive Science Society, Wednesday, July 23 - Saturday, July 26, 2014, cognitivesciencesociety.org/conference2014

UAI 2014
Annual Meeting of the Conference of Uncertainty in Artificial Intelligence, Wednesday, July 23 - Sunday, July 27, 2014, www.auai.org/uai2014/

CNS 2014
Annual Meeting of the Organization for Computational Neuroscience, Saturday, July 26 - Thursday, July 31, 2014, www.cnsorg.org/cns-2014-quebec-city

AAAI 2014
Annual Meeting of the Association for the Advancement of Artificial Intelligence, Sunday, July 27 - Thursday, July 31, 2014, www.aaai.org/Conferences/AAAI/aaai14.php

AGI 2014
The Seventh Conference on Artificial General Intelligence, Friday, August 1 - Monday, August 4, 2014, agi-conf.org/2014/

Presentation Guidelines

Talks

There will be three parallel talk sessions in rooms Port-Neuf & Ste-Foy, Courville & Montmorency and Palais on Saturday, Sunday, and Monday consisting of 20-minute slots for every talk (15 min. talk + 5 min. for discussion). It is recommended to respect the time alloted to offer everyone the opportunity to switch sessions in order to hear specific talks.

In all the rooms you will find the option to connect your own computer or tablet to the presentation equipment. In case you plan to use the local computer, please give your presentation in PDF or PowerPoint format to the technical room assistant before the session starts.

Keynote Speakers

The invited talks by Horace Barlow, Richard S. Sutton and Wolf Vanpaemel will be held on Saturday, Sunday and Monday respectively at 9:00 a.m., 10:30 a.m., and 10:30 a.m., respectively in room Palais. Full descriptions are given below.

Workshop

A workshop on Gaussian Processes in Psychology will be held on Sunday in room Palais at 14:00 p.m. Full descriptions is given below.

Invited Symposia

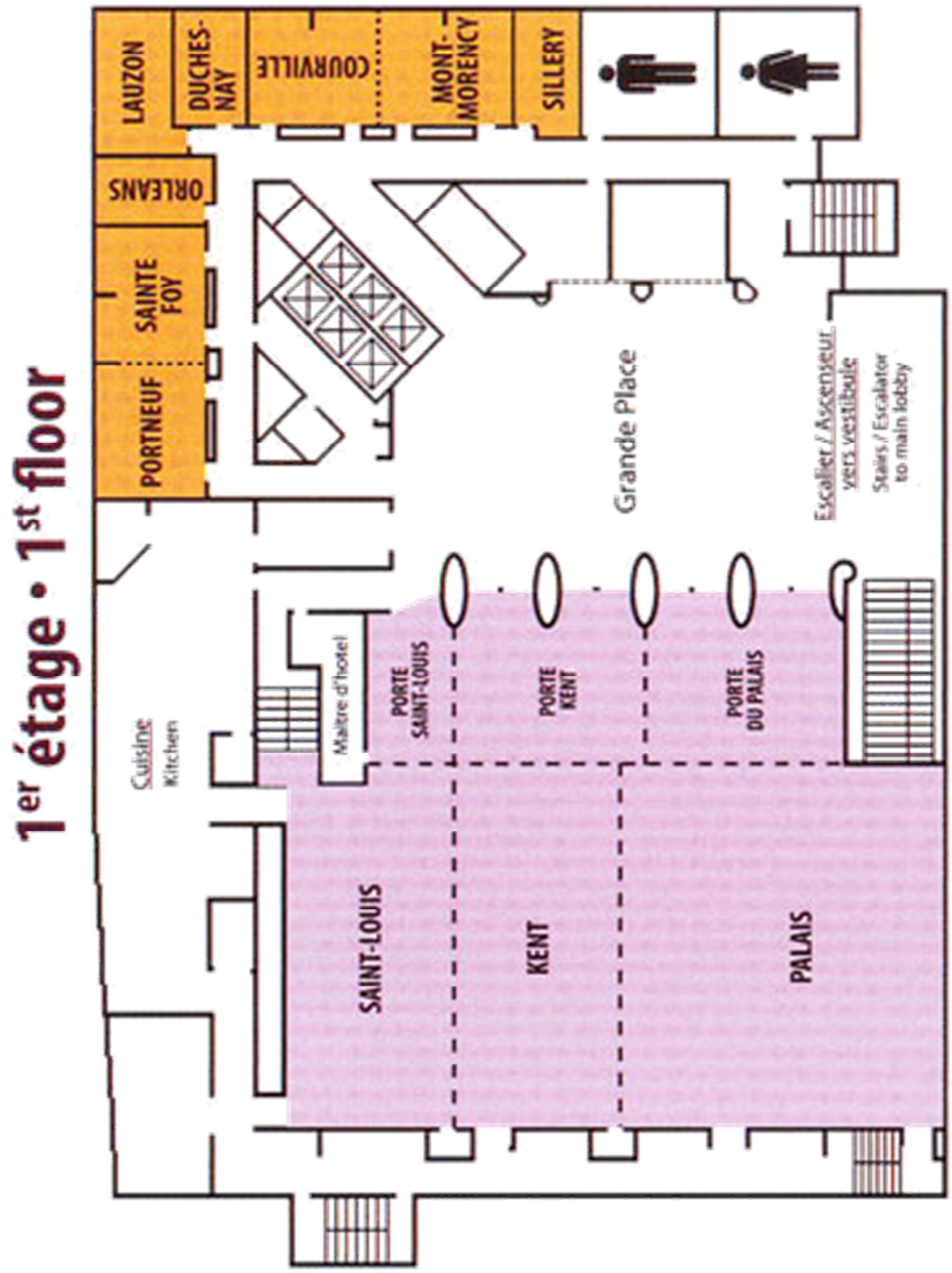
There will be three invited symposia in room Palais. The first symposium begins on Saturday at 10:30 a.m. titled "Symmetry: Theory and Applications" (Chair: Zygmunt Pizlo and Manish Singh). The next day at

9:00 a.m., the second symposium is entitled "Contextualized Probability Theories" (Chair: Jerome Busemeyer and Zheng Joyce Wang). The third symposium will be on the last day, entitled "The same-Different task: Things are the same 50 years later" (Chair: Denis Cousineau), starting at 9:00 a.m.

Posters

The posters will be on display from Friday 4:00 p.m. to Monday 7:00 p.m. The poster session will take place on Saturday, from 5:20 p.m. to 7:30 p.m. in the room Kent. Please look up your poster ID in this booklet and attach your poster to the corresponding poster board. The size of the poster board is 1.20 m (width) $\times$ 1.20 m (height).

Floor Plan


1er étage • 1st floor
LAUZON
DUCHES-NAY
COURVILLE
MONT-MORENCY
SILLERY
ORLEANS
SAINTE FOY
PORTNEUF
Grande Place
Escalier / Ascenseur vers vestibule
Stairs / Escalator to main lobby
Cuisine
Kitchen
Maître d'hotel
PORTE SAINT-LOUIS
PORTE KENT
PORTE DU PALAIS
SAINT-LOUIS
KENT
PALAIS

Restaurants

The conference is conveniently located near the Old Quebec and Grande-Allée, two areas of Quebec city known their rich cuisine.

Here is a list of recommended and popular restaurants near the conference's location. We strongly encourage you to visit and explore these areas and sample what Quebec has to offer.

Restaurants

1-Beffroi Steak-House
2-Hobbit Bistro
3-Rotisserie St-Hubert
4-Galerie Libanaise
5-Taverne Grande-Allée
6-La Petite Italie
7-L'atelier – Tartares et Cocktails
8-Piazz Boite à Chansons
9-La Piazetta
10-Lasagne et Cucina Restaurant
11-Chez l'Autre
12-Tokyo
13-Saint Amour
14-La Cremalière
15-Lapin Sauté
16-Entrecôte Saint-Jean
17-Asia Restaurant Quebec
18-Portofino Bistro
19-Toast
20-Côtes A Côtes
21-Sous-le-Fort et Bistro
22-La Pizz
23-L'Accent
24-Il Teatro
25-Aux Anciens Canadiens

Coffee shop

1-Restaurant Café du Monde
2-Tim Horton's
3-Starbucks
4-Second Cup

Pharmacy

1-Pharmaprix

Hospital

2-Hôtel-Dieu de Québec

Grocery Store

1-Épicerie J.A Moisan

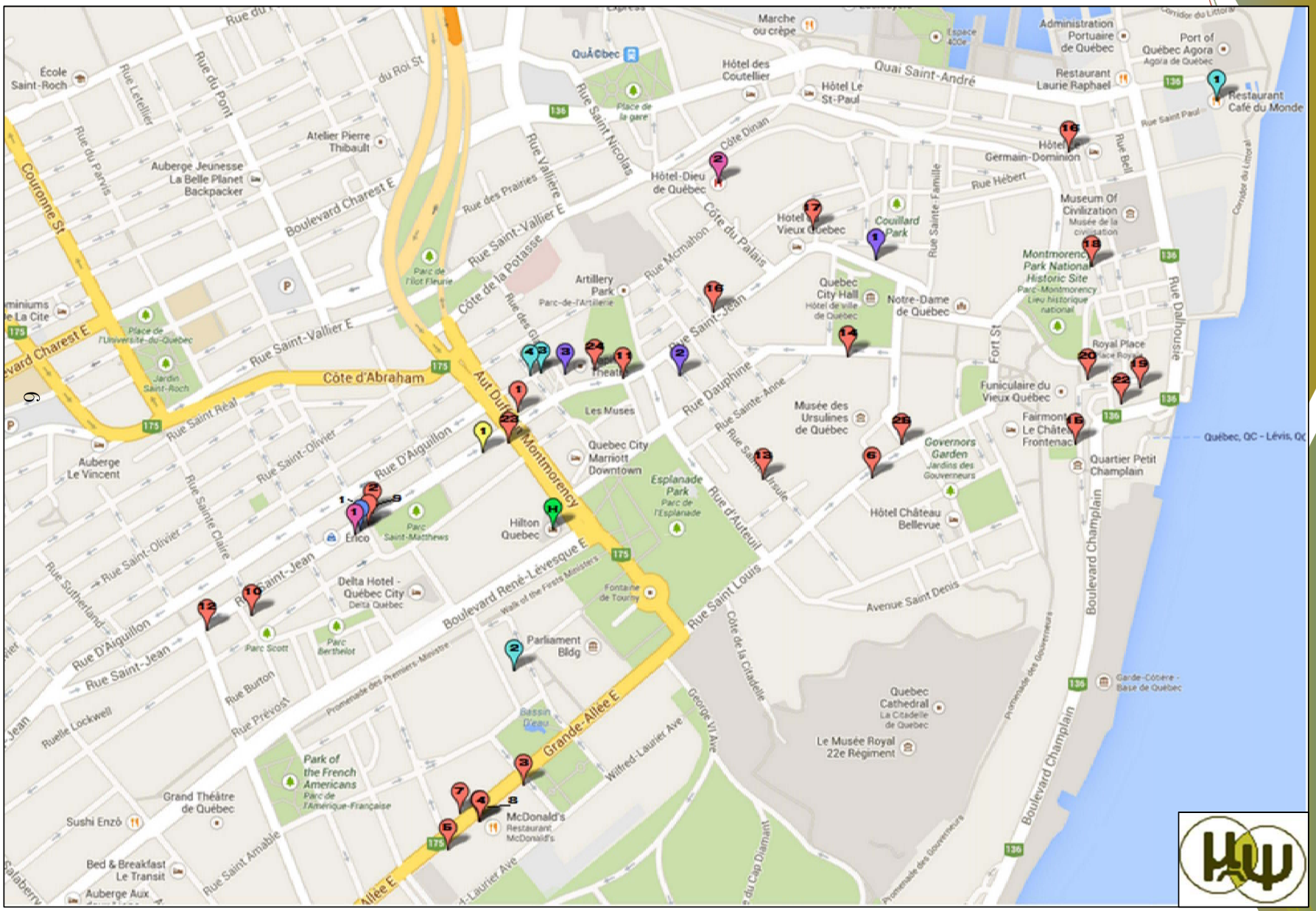
Convenience

1-Couche-Tard
2-Marché du Quartier
3-Jac & Gil Inc

Liquor Store

1-SAQ

A few restaurants and convenient stores around the hotel (H)



Pre-Conference: Meeting of the Women of Mathematical Psychology

Friday, 1:30 pm
Courville & Montmorency
Negotiation: Data and Advice

The mission of the Women of Mathematical Psychology group is to support the inclusion and retention of women in the Society. Toward that goal, we have hosted a symposium for the past several years highlighting challenges faced by women in science. The theme of this year's symposium is negotiation. Negotiation is a critical, but often underdeveloped, skill. The symposium will present empirical evidence about the relationship between gender and negotiation and offer practical advice.

Themes:

- Women and negotiation (Amy Criss, Syracuse University)
- Perspectives on negotiation from a former department Head (Philip Smith, University of Melbourne)
- Panel (Pernille Hemmer, Rutgers University, Michael Kalish, Syracuse University, Leslie Blaha, Air Force Research Laboratory)

We welcome *all* who are interested in this topic (not just women) to attend!

Organizers: Pernille Hemmer, Jennifer Trueblood and Annemarie Zandscholten.

Abstracts For Keynote Talks

Saturday, 9:00
Palais
Chair: Zigmunt Pizlo

Symmetry and the computational goals that underlie perception HORACE BARLOW, *University of Cambridge, United Kingdom* ■ Although I am (or was) a neurophysiologist, I do not think records of impulse trains from neurons in perceptual systems can be interpreted properly until we answer the question "What are the goals of the computations these systems and their neurons are performing?" This is simply because you cannot test whether a system does the job you think it may do unless you have ideas about what that job is. The proposition I like the sound of, and shall argue for here, is that the two main computations in early vision are cross-correlation of patches of the image with fixed templates, and auto-correlations of pairs of image patches related by some specified transformations. One definition of symmetry is "invariance under transformation", so is symmetry detection the main computational goal of early vision? This is the first point to be discussed, and I think it turns out that the answer is "Yes", but perhaps this applies only to some, not all, of the transformations you might wish to include in the definition of symmetry. The second question is "How does detecting symmetry help?" Symmetries are forms of regularity or redundancy, and if you know about them you can make more reliable and sensitive predictions than if you don't, and you will have potentially serious cognitive advantages over your competitors. There are some ancient observations on the way that damage to the visual cortex interferes with the orienting response that tend to support these views. It should be possible to allocate specific types of symmetry detection to specific cortical areas neurophysiologically, or possibly using fMRI. Some preliminary psychophysical experiments capable of measuring the absolute efficiencies for detecting non-random or non-independent positioning of dots in otherwise random arrays have already given encouraging preliminary results. I think the view that symmetry detection is the main new trick of the cerebral cortex deserves closer examination.

Sunday, 11:30
Palais
Chair: Sebastien Helie

Reinforcement Learning and Psychology: A Personal Story RICHARD S. SUTTON, *University Of Alberta, Edmonton* ■ The modern field of reinforcement learning (RL) has a long, intertwined relationship with psychology. Almost all the powerful ideas of RL came originally from psychology, and today they are recognized as having significantly increased our ability to solve difficult engineering problems such as playing

backgammon, flying helicopters, and optimal placement of internet advertisements. Psychology should celebrate this and take credit for it! RL has also begun to give something back to the study of natural minds, as RL algorithms are providing insights into classical conditioning, the neuroscience of brain reward systems, and the role of mental replay in thought. I have been working in the field of RL for much of this journey, back and forth between nature and engineering, and have played a role in some of the key steps. In this talk I tell the story as it seemed to happen from my point of view, summarizing it in four things that I think every psychologist should know about RL: 1) that it is a formalization of learning by trial and error, with engineering uses, 2) that it is a formalization of the propagation of reward predictions which closely matches behavioral and neuroscience data, 3) that it is a formalization of thought as learning from replayed experience that again matches data from natural systems, and 4) that there is a beautiful confluence of psychology, neuroscience, and computational theory on common ideas and elegant algorithms.

Monday, 11:30
Palais
Chair: Mark Steyvers

Five routes to better models of cognition Wolf Vanpaemel, *KU Leuven, Belgium* ■ An important goal in cognitive science is to build strong and precise formal models of how people acquire, represent, and process information. I argue that there are several invaluable but under-used ways in which models of cognition can be improved. I present a number of worked examples to show how models of cognition can be enhanced by: relying on (prior) predictions rather than on post(erior pre)dictions; reducing dependence on free parameters by capturing theory in the prior; fighting the Greek letter syndrome by testing selective influence; engaging in model expansion; and taking the plausibility of data into account when testing models. Adopting these modeling practices will require modelers to be creative and to overcome their hypochondriacal fear of subjectivity, but will lead to an increased understanding of cognition.

Abstracts For Plenary Talks

Sunday, 16:00
Palais
Chair: Denis Cousineau

A crowd-sourced scheduling system for academic conference
Joachim Vandekerckhove, *University of California, Irvine*
■ I will present preliminary results of a crowd-sourced scheduling system for the Math Psych conference. The system is based on feedback solicited from conference speakers at the time their abstracts are accepted and they are asked to confirm their attendance. A simple and anonymous survey will be used to determine which spoken presentations tend to attract similar attendants, and submitted category labels will be used to group talks. This information will then be used to construct a loss function that quantifies (a) the amount of conflict created by similar talks scheduled at the same time in different rooms and (b) the consistency of topics within a session. Optimizing this loss function over the space of possible schedules may yield a conference schedule that causes minimal frustration on the part of the attendants.

Monday, 15:30
Palais
Chair: Denis Cousineau

Moving past BMS and MDL: Making model evaluation rational
Richard M. Shiffrin, *Indiana University, Bloomington, Indiana*
■ I present a generalization of Bayesian Model Selection in which models are treated as greatly simplified but useful accounts. The goal is to use the observed data to induce the probabilities that each model provides the best approximation to the true model and the data produced by that true model. Induction and inference are conditional upon some criterion of best approximation that must be chosen in accord with one's goals and task. The approach accords with actual scientific practice, allows one to place the emphasis on data rather than models, allows one to incorporate prior knowledge about both data and models (because there is a direct correspondence between the two), and allows one to incorporate qualitative criteria into quantitative model selection. The key insight is based on the idea that the true model produces a distribution of outcomes for a given experiment, that the observed data are a sample from that true distribution, and that Bayesian induction provides posterior probabilities that each model produces a distribution that best approximates that true distribution, conditional on an observed sample from that true distribution, a goodness of fit

criterion, and prior knowledge that allows one to assign prior probabilities to both data distributions and models.

Abstract For Workshop

Sunday, 14:00
Palais

An Introduction to Gaussian Processes in Psychology Joseph W. Houpt, *Wright State University, Dayton, Ohio* , Gregory E. Cox, *Indiana University, Bloomington, Indiana* , Richard M. Shiffrin, *Indiana University, Bloomington, Indiana* ■
While point estimates, such as mean response times, have been the focus of many studies in scientific psychology, there is increasing appreciation of the value of functional data. In some cases it is possible to reduce the functional data to points and use the familiar statistics with those estimates, however, to take full advantage of the power of functional data, we need statistical tools specifically for functional data. In this workshop we will introduce the use of Gaussian processes for functional data. Much as the Gaussian distribution is the foundation of many statistical analyses of point data, the Gaussian process has the potential to be used for many types of analyses of functional data. We will begin the workshop with a general introduction to the Gaussian process. This will include some basic properties, with a bias toward those properties that are most important to psychological researchers. We will then highlight some of the more familiar statistical tools that can be reframed in terms of Gaussian processes. This will lead into a more in depth discussion of Gaussian process regression. Once we have introduced Gaussian process regression, we will work with participants to analyze functional data using R statistical software with packages available on CRAN. We will have two data sets available for learning the techniques. One data set is a set of paths of mouse movements in a simple decision making task. With the second dataset, we will use Gaussian processes to estimate psychometric curves in a visual detection task. Tutorial participants are also encouraged to bring their own data, which may benefit from analysis with Gaussian processes.

Abstracts For Symposium Talks

Symposium abstracts organized by day and presentation order

Symmetry: Theory and Applications

Organizers: Zygmunt Pizlo and Manish Singh

Saturday, 10:30
Port-Neuf & Ste-Foy

Symmetry: Theory and Applications Zygmunt Pizlo, *Purdue University, Indiana*, Manish Singh, *Rutgers University, New Brunswick, New Jersey* ■ Symmetry has a solid foundation in mathematics where it refers to invariance with respect to a group of transformations. When viewed from an information-theoretic standpoint, symmetry is thus a form of redundancy. For years, symmetry has played a central role in art, esthetics, architecture, physics, and computer science. It has recently started playing a similar role in human and computer vision as well. Symmetry is widely prevalent in the natural environment; and symmetric structures are inherently simpler. For both reasons, symmetry can serve as a powerful "prior" that perceptual systems can use to infer invariant 3D structure from 2D images. Moreover various forms of symmetry can be used to represent the shape of complex objects in a compact manner. This symposium will explore various types of symmetry and their role in perception and cognition.

Saturday, 10:30
Port-Neuf & Ste-Foy

Computational Symmetry and Computational Regularity Yanxi Liu, *Pennsylvania State University, University Park, Pennsylvania* ■ Symmetry is an essential mathematical concept, as well as a ubiquitous, observable phenomenon in nature, science and art. Either by evolution or by design, symmetry implies an efficiency coding that makes it universally appealing, especially so in machine visual perception of the real world. Alas, recognition of real world (digital) symmetry remains a challenging problem that has been puzzling computer vision and psychology researchers for decades. We explore a formal and computational characterization of real world symmetry using a hierarchical model of symmetry groups. Such a formalization simultaneously facilitates: (1) a robust and comprehensive algorithmic treatment of the whole regularity spectrum, from regular (perfect symmetry), near-regular (approximate symmetry), to various types of irregularities; (2) an effective detection scheme for real world symmetries and symmetry groups; and (3) a set of computational bases for measuring and discriminating quantified regularities on diverse data sets. I shall illustrate various recent progress of computational regularity and computational symme-

try in texture analysis, tracking, and manipulation; skewed-rotation, curved-glide reflection detection, and translation symmetry perceptual grouping in urban scenes. Recent progress includes "GRASP Recurring Patterns from a Single View", "Symmetry of Dance" and "Local regularity-driven city-scale facade detection from aerial images".

Saturday, 11:00
Port-Neuf & Ste-Foy

Asymmetry: what sort of perceptual quantity is it? Bosco S. Tjan, *University of Southern California, Los Angeles, California*, Zili Liu, *University of California, Los Angeles, California* ■ Human sensitivity to changes along a basic perceptual dimension (e.g. loudness) often decreases as the underlying physical quantity (e.g. sound pressure) increases. Such relationship between physical and perceptual quantities is often described by Weber-Fechner's or Stevens' law. We found that the perception of asymmetry "deviations from bilateral symmetry" has a sensitivity profile opposite to this general pattern: sensitivity improves with increased asymmetry. This is especially the case when asymmetry is introduced with smooth structural deformation, which is the common form of asymmetry in biological shapes or from viewing human-made object at an oblique angle. The observed sensitivity profile is consistent, from a Bayesian perspective, with the assumption that objects are often symmetric. On the other hand, when asymmetry is introduced by randomly displacing or replacing features, an arguably non-natural way of introducing asymmetry, sensitivity decreases with increased asymmetry. We showed that a single and simple image-processing model can explain both sets of results. The model does not treat asymmetry as a "basic" perceptual dimension. Instead, asymmetry is computed as a derived quantity (a difference of differences) based on more basic perceptual quantities that are perceived in accordance with Weber-Fechnerâ's or Stevens' law. Intriguingly, there may be a fundamental link between perceptual bias (e.g. biased towards perceiving symmetry) and derived (as opposed to "basic") perceptual quantity.

Saturday, 11:30
Port-Neuf & Ste-Foy

A Frame-of-Reference Principle in Human Symmetry Processing Revealed by Rapid Redeployment of the Symmetry Axis Preference Christopher W. Tyler, *The Smith-Kettlewell Eye Research Institute, San Francisco, California* , Chien-Chung Chen, *National Taiwan University, Taipei, Taiwan* ■ It is easier to detect symmetry about a vertical axis than about any other orientations, an effect that has been linked to evolutionary adaptation to environmental contingencies. However, Tyler, Hardage & Miller (1995) found no axis orientation bias in a block-design paradigm, and Wenderoth (1994) found that axis preference could be reversed by biased sampling of axis orientation in a randomized design. To investigate this adaptability, we precued the observers to symmetry axis orientation before they had to detect a symmetric pattern of one of four possible orientations in a randomized design. The cue was either valid or neutral. The symmetry patterns were seen through apertures that either obscured or revealed the symmetry axis. Vertical advantage was observed in all the neutral cue conditions but was eliminated, or reversed, in the valid cue conditions. Our result cannot

be explained by a hard-wired, filter-based mechanism, but requires an allocation of perceptual resources in the visual processing based on the cueing information. The vertical advantage is thus a Bayesian precueing of the vertical axis by the visual system, as it is the most probable symmetry orientation based on short-term past experience.

Saturday, 12:00
Port-Neuf & Ste-Foy

The Perceived Symmetry of Regular Patterns is Local Michael Kubovy, *University of Virginia, Charlottesville, Virginia* ■ In this paper I argue for a perception-based description of regular patterns in the plane. I show that the group-theoretic characterization of patterns fails to capture the way they are perceived. I will show that two patterns of the same formal type may look different for reasons that cannot be captured by geometry. Our effort will be devoted to the study of one-dimensional patterns (a.k.a. friezes or band designs) and of two-dimensional patterns (a.k.a. wallpaper patterns or tilings). The first discrepancy regards the way symmetries such as rotation and reflection are perceived.This is the phenomenon of locality (rather than globality) of perceived symmetries. For example, the mathematician will describe the frieze . . . pqpqpqpq . . . (which has two isometries, translation and reflection) as having multiple disjunctive ways of applying the reflection isometry to the pattern as a whole and thus mapping it onto itself. In contrast, we perceive these mirrors as multiple conjunctive transformations applied to parts of the pattern. The second discrepancy regards the effect of of changes in the location of copies of the motif of a regular pattern. Even though the formal description of a pattern may remain unchanged in the face of such spatial changes, the perceiver's description of the pattern may be strikingly different. I propose some explanations for this discrepancy.

Saturday, 14:00
Port-Neuf & Ste-Foy

2D images of a 3D symmetrical shape and 3D interpretations of a 2D symmetrical image Tadamasa Sawada, *State University of New York College of Optometry, New York, New York* ■ Human visual system is sensitive to 2D symmetry in a retinal image. It has been shown that 3D symmetry of an object's shape is a very effective a priori constraint for recovering the 3D shape from its single 2D image. However, a 2D symmetrical image of the 3D symmetrical shape is rather accidental and is actually a degenerate case for the recovery. How can the human visual system detect 3D symmetry from a 2D asymmetrical image? Why is the human visual system sensitive to 2D symmetry of a retinal image? Note that 3D symmetry alone is not enough for the visual system for detecting 3D symmetry. I will show that there always exists a 3D symmetrical interpretation for any given 2D image and how the detection becomes possible by introducing an additional constraint of the 3D shape. There are invariant features of 3D symmetry that are preserved in the 2D image of the 3D shape if the 3D shape satisfies the additional constraint (planarity of contours) together with 3D symmetry. I will also discuss a role of 2D symmetry in perception of a 3D scene outthere.

Saturday, 14:30
Port-Neuf & Ste-Foy

Detecting and Grouping Symmetric Parts in Cluttered Scenes
Sven Dickinson, *University of Toronto, Toronto, Ontario* ■ Perceptual grouping played a prominent role in support of early object recognition systems, which typically took an input image and a database of shape models and identified which of the models was visible in the image. Using intermediate-level shape priors, causally related shape features were grouped into discriminative shape indices that were used to prune the database down to a few promising candidates that might account for the query. In recent years, however, the recognition (categorization) community has focused on the object detection problem, in which the input image is searched for a specific target object. Since indexing is not required to select the target model, perceptual grouping is not required to construct a discriminative shape index. As a result, perceptual grouping activity at our major conferences has diminished. However, there are clear signs that the recognition community is moving from appearance back to shape, and from detection back to multi-class object categorization. Shape-based perceptual grouping will play a critical role in facilitating this transition. In this talk, I will describe our recent progress on detecting and grouping symmetric parts in cluttered scenes. Drawing on the concept of Blum's medial axis transform (MAT), we construct medial axis approximations by grouping together deformable maximal inscribed disks modeled as superpixels. The grouping process is governed by a symmetry prior that's learned from examples. Detected parts are then grouped to form objects using learned part attachment regularities.

Saturday, 15:00
Port-Neuf & Ste-Foy

Bayesian Hierarchical Grouping: A probabilistic approach to skeleton-based representation of shape
Vicky Froyen, *Department of Psychology and Center for Cognitive Science, Rutgers University - New Brunswick, NJ*, Jacob Feldman, *Department of Psychology and Center for Cognitive Science, Rutgers University - New Brunswick, NJ*, Manish Singh, *Department of Psychology and Center for Cognitive Science, Rutgers University - New Brunswick, NJ* ■ Representations of shape based on local symmetry, such as the medial axis transform (MAT), have played a prominent role in theories of visual shape and its application to shape recognition ever since their introduction by Blum (1967; 1973). Unfortunately, because of their deterministic nature, existing methods are highly sensitive to boundary noise and often yield unintuitive results with simple shapes. We discuss a probabilistic approach to medial shape representation, recasting shape representation as an estimation problem, which avoids many of these traditional problems. Our approach generalizes to the broader problem of perceptual grouping, yielding a framework we call Bayesian Hierarchical Grouping (BHG). In BHG we assume that the configuration of edge elements of a shape is generated by a mixture of skeletal axes, where each axis generates edge elements according to a stochastic generative model (a generalized formulation of the generative model proposed by Feldman and Singh, 2006). The union of all axes then forms the skeleton of the shape. Thus, in

our framework, part decomposition, means estimating the number of components in the mixture (i.e. the skeletal axes) that generated the shape, including which edge elements are owned by which axis. We present a tractable implementation of this framework based on the hierarchical clustering approach by Heller and Ghahramani (2005). Our approach yields an intuitive hierarchical representation of the shape, giving an explicit decomposition of the shape into parts, along with estimates of the probabilities of various candidate decompositions.

Saturday, 16:00
Port-Neuf & Ste-Foy

Breaking the Symmetry in Shape from Shading Steven W. Zucker, *Yale University, New Haven, Connecticut*, Benjamin Kunsberg, *Yale University, New Haven, Connecticut* ■ The inference of shape information from shading is a classical inverse problem: it is difficult precisely because many combinations of surface geometry and light sources can give rise to an identical shading distribution. The size of this equivalence class is a type of symmetry; the challenge is to break the symmetry. We are developing a geometrical approach to shape-from-shading that is based on the shading flow, a model of how shading information could be represented in cortex. Our analysis provides a characterization of these equivalence classes, within which light source properties reduce to image features. Most importantly, we show how the ambiguity concentrates for certain characteristic features, or surface patches on which the shading inference can be anchored. These anchors break the symmetry in the general problem.

Saturday, 16:30
Port-Neuf & Ste-Foy

Symmetry, Measurement, and the Erlanger Program Louis Narens, *University of California, Irvine, California* ■ The nineteenth century Erlanger Program for geometry provided means of classifying known geometries and discovering new ones. Its key concept was invariance under a group of symmetries. The Erlanger Program also provided a formal definition of the geometrical content inherent in quantitative models. This talk describes a similar approach that has been undertaken in the modern theory of measurement. It also provides a useful generalization of invariance for scientific epistemology that does not employ the notion of "transformation" or its natural mathematical generalizations (morphisms). The new generalization of invariance is used fill an important epistemological gap in the Erlanger Program.

Saturday, 17:00
Port-Neuf & Ste-Foy

Perspectivity, Projectivity, and Binocular Vision Jun Zhang, *University of Michigan, Ann Arbor, Michigan* ■ We investigate the role of projective geometry in forming the perceptual space for binocular vision. Binocular vision involves the projection of objects in the 3-D visual space onto the two retinae and the comparison of spatial layout of objects in these retinal half-images. We characterize the unitary representation of the binocular space from the perspective of the cyclopean eye as a complex half-plane, and investigate its automorphism group, namely the Moebius transformation group. With the two eye positions are treated as fixed points of the automorphism, we

show that the geometry is that of the hyperbolic space with constant negative Riemannian curvature (Poincare upper halfplane model), and obtain its only invariants, namely the "four-point ratio", reflecting the fact that the relative disparity between any two object points remains unchanged when the eyes change fixation. We show that the hyperbolic tangent function $f(z) = tanh(z)$, with inverse $g(z) = 1/2log(1+z)/(1-z)$, act as the psychophysical function relating the physical representation of the binocular space to its cyclopean representation. Lastly, we discuss a lattice- theoretic axiomatization of projective geometry (by Von Neumann) and speculate its relevance to perceptual apparatus for perspectivity and projectivity in vision and cognition.

Contextualized Probability Theories

Organizers: Jerome R. Busemeyer and Zheng (Joyce) Wang

Sunday, 9:00
Port-Neuf & Ste-Foy

Contextualized Probability Theories Jerome R. Busemeyer, *Indiana University, Bloomington, Indiana*, Joyce Zheng, *Ohio State University, Ohio* ■ Contextualized probability theories concern the problem of joining together in a coherent manner a set of unrelated probability distributions. These unrelated distributions occur under different experimental conditions (contexts). This issue often arises in "big data" problems. Consider the following very simple example. Suppose we have four binary valued questions and each condition is formed by asking about the probability of the conjunction of the two questions. There are six conditions formed by the six ways to combine two pairs of questions from a set of 4 questions. Each of these six conditions produces a two-way joint probability distribution. How can we join together these six two-way tables into one coherent probability theory? One answer might be to derive each of these 6 two-way tables from a single 4-way joint distribution, but this might turn out to be impossible! In the latter case, what can one do? What is needed for to address these issues is a contextualized theory of probability.

Sunday, 9:10
Port-Neuf & Ste-Foy

What is complementarity and compatibility in quantum cognition? Joyce Zheng, *Ohio State University, Ohio* ■ One of the most important differences between Kolmogorov and quantum probability theories is the introduction of the property of compatibility/incompatibility in the latter. Psychologically, two measurements are compatible if they can be considered simultaneously, one does not interfere with the other, and order of evaluation does not matter; otherwise they are incompatible. Formally, two measurements are compatible if they can be represented within the same basis, and so their projectors commute; otherwise they are incompatible. If all of the measures commute, then Kolmogorov and quantum theories are equivalent. How can we determine a priori whether or not two measurements are incompatible? And if they are, how can we determine the change in basis for these incompatible events? We consider an example of measurement for "self" (e.g., do you like this object?) versus "other" (do you think your friend

will like this object?) by the same person, and we argue that these questions are incompatible. We empirically demonstrate that they produce strong order effects, and we develop and test a quantitative model that describes the change in basis when judgments are made from the different perspectives of "self" versus "other."

Sunday, 9:38
Port-Neuf & Ste-Foy

Three Approaches to Making World Kolmogorovian Ehtibar Dzhafarov, *Purdue University, Indiana* ■ The talk compares three approaches to "sewing together" different sets of random variables observed under mutually incompatible conditions: contextuality-by-default (Dzhafarov-Kujala), conditionalization (Avis-Fischer-Hilbert-Khrennikov), and signed probability measures (de Barros-Oas, Abramsky-Brandenburger). Both contextulaity-by-default and signed probabilities allow one to distinguish different types and degrees of contextuality. Conditionalization is uninformative in this respect, although universally applicable. There are rather striking mathematical equivalences between contextulaity-by-default and signed probabilities: for example, in the analysis of inconsistent judgments by different judges, and in the Alice-Bob entanglement paradigm, they provide measures of contextuality that are linearly related to each other.

Sunday, 10:05
Port-Neuf & Ste-Foy

The Logical Structure of Contextual Effects Louis Narens, *University of California, Irvine, California* ■ Recently, Hilbert space modeling from quantum mechanics has been introduced into cognitive psychology to model contextual effects and other perplexing psychological phenomena. In 1936 Birkhoff and von Neumann described the algebraic/logical structure inherent in Hilbert space modeling, and a modest generalization of this became the much studied area in mathematics, physics, and philosophy that is today called "quantum logic", which is a generalization of classical propositional logic. This talk derives a model of quantum logic from considerations about how experimenters reason across experiments in which the participants are put into different contexts. The derivation takes place in standard probability theory.

Sunday, 10:33
Port-Neuf & Ste-Foy

A Quantum Probability Approach to Human Causal Reasoning Jennifer S. Trueblood, *University of California, Irvine, California* ■ When people make inferences about causal situations with vague and imperfect information, their judgments often deviate from the normative prescription of classical probability. As a result, it is difficult to apply popular models of causal reasoning such as delta P and causal power, which provide good accounts of behavior in casual learning tasks and tasks where statistical information is provided directly. We propose a unified explanation of human causal reasoning using quantum probability theory that can account for causal reasoning across many different domains. In our approach, we postulate a hierarchy of mental representations, from fully quantum to fully classical, that could be adopted for different situations. We illustrate our

approach with new experiments and model comparisons.

The "Same"-"Different" task: Things are the same 50 years later

Organizer: Denis Cousineau

Monday, 9:00
Port-Neuf & Ste-Foy

The "same"-"different" task: Things are the same 50 years later Denis Cousineau, *University of Ottawa, Ottawa, Ontario* ■ The "same"-"different" task, also commonly called the matching task or the comparison task, is a classic paradigm in cognitive psychology, explored by Bamber, Nickerson, and Egeth, among others. One salient aspect of the results was the "fast-same phenomenon" where "same" responses were sometimes considerably faster than any of the fastest "different" responses, despite the fact that logic suggests that "same" must be exhaustive whereas "different" doesn't have to be. The early research culminated in reviews and syntheses in the 1980's (e.g., Proctor, 1980, Farell, 1985, and Sternberg, 1998). Afterwards, research on this paradigm came to a near stop and since then, few newer contributions have been proposed. Considering the vast amount of research conducted on close topics, such as priming, short term memory, feature extraction, redundant target detection, novelty detection, sampling models, etc., the near absence of new propositions regarding the "same"-"different" task is rather surprising. In this symposium, I invite researchers to propose new leads on the comparison task. Their perspectives on priming, attention, and memory should provide fruitful new approaches to understand the processes underlying performances in this task.

Monday, 9:30
Port-Neuf & Ste-Foy

Priming and Same-Different Tasks: Processing During the First Four Seconds Bruno G. Breitmeyer, *Department of Psychology, Center for Neuro-Engineering and Cognitive Science; University of Houston, Houston, Texas*, Jane Jacob, *Department of Psychology, University of Houston, Houston, Texas* ■ Priming tasks and same-different comparison tasks require speeded perceptual judgments to be made of a second of two sequentially presented stimuli. Even for stimulus onset asynchronies (SOAs) ranging up to several seconds, a priming task relies only on "on-line" iconic sensory memory lasting about 700 ms, whereas the comparison task additionally relies on transfer of information from iconic memory to "off-line" post-iconic, short-term memory levels of processing. Previously we explored these two tasks for SOAs ranging from 0 to 2,000 ms. Here we report results obtained for SOAs ranging from 0 to 4,000 ms. We replicate the main findings of the earlier study, showing the involvement of two stages of iconic memory and of a third post-iconic stage of visual working memory (VWM), and we additionally report subsequent phases of processing in VWM beyond the first 2,000ms. While the first three stages characterize active processing of information in iconic memory and its transfer to VWM, the subsequent phases in VWM appear to indicate fluctuations of attention to items stored there. These findings are important methodologically for investigating, and theoretically for understanding, not only stimulus priming and

comparison tasks but also the consolidation and storage of information in VWM.

Monday, 10:00
Port-Neuf & Ste-Foy

Attentional Episodes and Comparison Operations Brad Wyble, *Pennsylvania State University, University Park, Pennsylvania* ■ While visual perception seems to be relatively continuous, some phenomena, such as the attentional blink, suggest that even in the absence of eye movements, visual input may be more accurately described as a series of discrete episodes that are stitched together, in a similar manner as a movie scene is composed of brief shots of varying length. We refer to these shots as attentional episodes in a recent computational model (Wyble et al. 2011, Wyble et al. 2009). In this model, detecting a target triggers a short period of attentional engagement ($\sim 150ms$ in duration) during which information is admitted for memory encoding. Importantly, one attentional episode may permit multiple stimuli to enter the encoding stage and the subsequent duration of encoding can be as long as hundreds of milliseconds, depending on the complexity of the information. Results from comparison and priming experiments (Jacob, Breitmeyer & Treviño 2013) provide a converging source of evidence about the temporal dynamics of attention. These results suggest that following a target onset, there is a brief window during which priming effects are enhanced, and comparison of two distinct stimuli can occur relatively more quickly. This window ends at about 200ms, which corresponds to the end of an attentional episode, as defined by the aforementioned model. My talk will discuss the temporal dynamics of comparison operations between multiple stimuli in the context of this model of attention.

Monday, 10:30
Port-Neuf & Ste-Foy

The fast-same effect and the habituation account of change detection Eddy Davelaar, *Birkbeck University of London, UK* ■ The fast-same effect is a well-known phenomenon in the same-different literature. However, recently, we showed that re-presentation of the same stimulus causes systematic slow down in a same-different task. In this talk, I will summarise research on how perceptual neural dynamics biases the brain toward processing novel or unexpected information. This can be achieved by perceptual discounting and is implemented using the neural phenomenon of synaptic depression (or neural fatigue or neural habituation). Neural responses to repeated stimuli reach a lower maximum than to novel stimuli. This novelty signal can be compared to a reference to perform a same-different judgment. In a sequential same-different task, we used pre-stimulus primes that were to be used to give the correct response to the stimulus, allowing perceptual presentation and response requirements to be deconfounded. We observed slower change detection (= responding 'different') when the stimulus repeated, irrespective of the response associated with its first presentation. This counters the fast-same effect, but is readily explained by the confounding of perceptual information and response requirement. When the appropriate (confounding) conditions are compared the fast-same effect returns.

Abstracts For Talks

Abstracts organized by day, session, and presentation order

Regular Session 1

Chair: Chris Donkin

Saturday, 10:30
Palais

ROC predictions of slots and resource models of visual working memory: Bayes Factors and Landscaping Chris Donkin, *UNSW, Australia*, Sophia Tran, *UNSW, Australia*, Robert Nosofsky, *Indiana University* ■ A fundamental issue concerning visual working memory is whether its capacity limits are better characterized in terms of a limited number of discrete slots (DSs) or a limited amount of a shared continuous resource. We compare the ability of these two models to account for data from five change-detection experiments. We use model selection methods that take into account the functional-form complexity of the models.

Saturday, 10:50
Palais

Modeling expert memory search, knowledge access, and decision making: A model of crossword puzzle play Shane Mueller, *Michigan Technological University, United States of America*, Kejkaew Thanasuan, *Michigan Technological University, United States of America* ■ Models of memory access and retrieval have typically examined laboratory experiments using arbitrary information over relatively short durations. As such, mathematical models of these processes often focus on mechanistic explanations of memory retrieval, rather than exploring conditions for representing, retrieving, and using the deep and vast knowledge humans use to make sense of the world and make decisions based on their expertise. To explore the requirements for representing such expert knowledge, we examine performance of crossword puzzle enthusiasts on a crossword paradigm, examining and modeling how they represent and retrieve knowledge based on both orthographic and semantic cues. This enables studying knowledge expertise in a constrained and well-mapped domain, using a database of approximately four million clues found in past puzzles. We propose a model of crossword play using this knowledge base, and along with being able to perform on par with crossword enthusiasts, the model enables us to examine the extent to which players use orthographic versus semantic routes to solve puzzle clues, and whether these two routes can be used together as a compound memory cue for retrieving puzzle answers. Results indicate that neither orthographic nor semantic-route cues alone can explain observed results, but a combined cue (semantic+orthographic) also fails to account for results. Instead, results are consistent

with the hypothesis that players use both routes independently, generating candidates from one route and checking these candidates against the other type of information. We conclude by discussing how in any knowledge-based decision, cues provide both memory activation and constraint, and hypothesize that experts in many domains must balance these two opposing forces in associative memory.

Saturday, 11:10
Palais

Beyond Correlated Model Fits of Continuous-Strength and Discrete-State Models of Recognition Memory Simone Malejka, *University of Mannheim, Germany*, Arndt Bröder, *University of Mannheim, Germany* ■ An ongoing debate in the recognition-memory literature revolves around the question whether evidence strength is continuous or discrete or, put differently, whether the number of likelihood ratios for target and lures corresponds to an infinite or finite number of evidentiary states. Continuous-strength models (e.g., signal detection theory) assume that evidence strength varies according to continuous probability distributions along a latent evidence dimension (e.g., Gaussian or logistic distributions). Old responses are given whenever the evidence value exceeds a response criterion. In contrast, discrete-state models (e.g., threshold models) postulate that evidence strength varies according to rectangular distributions, giving rise to certainty and uncertainty states. Old and New responses are given when the evidence value exceeds the respective detection threshold; otherwise a response is guessed. Despite the different assumptions of the rival approaches, similar conclusions were drawn from their measures and their goodness-of-fit to empirical data is highly correlated. In an attempt to reconcile divergent model assumptions and converging empirical findings, it is proposed that empirical evidence distributions deviate more or less from continuous distributions into the direction of rectangular distributions. In a series of experiments, the authors (a) investigated model fits to binary Receiver Operating Characteristic (ROC) data and (b) explored the shape of the evidence distributions on aggregated and individual level using the Tukey-lambda distribution. This family of distributions contains Gaussian, logistic, and rectangular distributions as special cases. The results account for overlapping conclusions and correlated model fits reported in the literature: Aggregated evidence distributions in recognition memory follow a hybrid distribution which is neither completely Gaussian nor completely rectangular, whereas individual evidence distributions are either Gaussian or rectangular in shape. Further implications for the question whether recognition performance should be analyzed assuming continuous or discrete evidence strength are discussed.

Saturday, 11:30
Palais

Mechanisms of Recognition Memory: Insights from a Dynamic Approach Gregory E. Cox, *Indiana University, United States of America*, Richard M. Shiffrin, *Indiana University, United States of America* ■ Models of recognition memory have typically assumed that memory retrieval and decision are two separate stages, with memory producing some static output (e.g., familiarity) that drives a secondary decision process (e.g., a random walk or diffusion). Cox and Shiffrin

(2012) have argued for a dynamic approach to recognition memory in which retrieval and decision interact: As time passes after presentation of a test item, more information joins a probe of memory, changing the response from memory over time; the evidence that drives a recognition decision thus changes from moment to moment. We present a formal model of the dynamics of the recognition process and use it to predict data from two large-scale studies of recognition accuracy and response time by Rae, Heathcote, Donkin, Averell, and Brown (in press) and Starns, Ratcliff, and McKoon (2012). Quantitative comparisons between different parameterizations of the model suggest that effects of normative word frequency on recognition are best attributed to information stored in semantic memory, rather than interference from specific prior episodes–an insight on a long-standing debate in the memory literature (c.f., Dennis & Humphreys, 2001) that would not have been possible within traditional two-stage models. Further comparisons with the Ratcliff (1978) diffusion model and the exemplar-based random walk model (Nosofsky & Palmeri, 1997) show that the fit of these models is drastically improved when evidence and decision criteria are allowed to change over time in a manner that mimics the new dynamic model, reinforcing the need–at least in these data–to consider the dynamics of how memory retrieval and decision jointly evolve over time.

Saturday, 11:50
Palais

Quantum refrigerators: A quantum model of conjoint recognition in natural scenes Jennifer S. Trueblood, *University of California, Irvine, United States of America*, Pernille Hemmer, *Rutgers University, New Brunswick, Piscataway, NJ* ■ The Episodic over-distribution Effect (e.g., Brainerd and Reyna, 2008) is a well established effect where the probability of accepting a studied target when asked if it is a target (p(T T)) plus the probability of accepting a studied target when asked if it is a related non target (p(T RT)) is greater than the probability of accepting a studied target when asked if it is either a target or a non related target(p(T T+ RT)). When sampled from one of three mutually exclusive and exhaustive categories - one is a target from the set of previously presented targets, a second is a non target but meaningfully related to a target, and a third is a non target and unrelated to any target - logically these two probabilities should be identical. We discuss two different models of the effect - a quantum recognition memory model (Busemeyer & Trueblood, 2010) and the overdistribution model (Brainerd et al., 1999). We apply both models to data from an item-memory conjoint recognition task where participants study natural scenes (e.g., kitchens and offices) and are probed with either target objects present in the scene, related target objects which were non-studied objects similar to the objects studied in the scene, or unrelated objects not presented in the scene or related to the scenes. The models are fit using hierarchical Bayesian parameter estimation. We also discuss the similarities and differences between the present quantum model and the recently proposed quantum episodic memory model (Brainerd et al., 2013), which was developed for the source-memory version of the conjoint recognition paradigm.

Saturday, 12:10
Palais

Interference effects of choice on con-

fidence reveal quantum nature of evidence accumulation Peter Kvam, *Michigan State University, United States of America*, Timothy Pleskac, *Michigan State University, United States of America*, Shuli Yu, *Michigan State University, United States of America*, Jerome R. Busemeyer, *Indiana University, United States of America* ■ Most models of decision-making derived from classical stochastic processing theories assume that evidence accumulation can be described by a single, definite trajectory across levels of evidence. In contrast, quantum probability models of decision-making posit that evidence can instead be represented as a wave-like superposition state, suggesting that a person may be considering many possible levels of evidence at any given time. This representation suggests that interference effects can appear when multiple responses about the same stimulus are elicited; in particular, making a decision should perturb subsequent distributions of confidence regarding the state of the stimulus relative to when no decision is made. We demonstrate this effect in a cued binary decision and confidence paradigm using a motion direction discrimination task. Decisions made during the task caused participants' subsequent confidence judgments to be more conservative, and as a consequence less overconfident, than an otherwise comparable condition in which they made no decision about the stimulus.

This qualitative finding poses a significant challenge to classical models generally, but we also conducted a Bayesian model comparison for a quantum random walk model against a similar Markov random walk. Using a grid approximation of the likelihood function for each model, we computed a Bayes factor for each of 9 participants as well as the overall fits. These overwhelmingly favored the quantum model, which was able to capture several characteristics of the data (the interference effect, multimodal gross shape, and wavy distributions) that are particularly problematic for a Markov model.

Regular Session 2

Chair: Ami Eidels

Saturday, 10:30
Courville & Montmorency

Can bimodality distinguish serial and parallel processes? Ami Eidels, *University of Newcastle, Australia*, Paul Williams, *University of Newcastle, Australia*, James Townsend, *Inidiana University* ■ Multiple signals, or attributes, may be processed in serial or in parallel. Early attempts suggested parallel and serial models can be teased apart by increasing the number of items in a display and observing response-times (RT). A serial model, according to this view, predicts increase in RT as a function of set size, whereas if processing is parallel RTs should be unaltered. However, Townsend (1990) and others have shown that parallel and serial processes can mimic each other in terms of their RT predictions. In the current study we show another kind of mimicry, where a parallel model can mimic what is often (mistakenly) considered to be a typical signature of a serial model. It is known that serial models can predict multimodal RT distributions, but it was unknown whether alternative architectures, such as parallel, can make such predictions. We show via simulations that a multimodal reaction time distribution is not sufficient to rule out parallel processing. These predictions are discussed within the context of recent data indicating

the existence of multi-modal distributions in visual search.

Saturday, 10:50
Courville & Montmorency

The role of false fixations of parameters in diffusion model analysis Veronika Lerche, *University of Heidelberg, Germany*, Andreas Voss, *University of Heidelberg, Germany* ■ The diffusion model (Ratcliff, 1978) is used in the analysis of data from binary classification tasks. It differentiates cognitive components such as speed of information accumulation and response criteria. Recent increases in the popularity of the model in different fields of psychology have brought issues concerning the practical applicability of the model into focus. When only small numbers of trials are used - as is often the case in studies with limited resources (e.g., time, stimulus material) - often more restricted versions of the diffusion model are applied in which certain parameters are fixed. It is unclear how this strategy affects parameter recovery and which, if any, parameters could or should be fixed. In simulation studies, this issue was addressed by the comparison of models with different numbers of falsely fixed parameters. The number of trials and the optimization criterion for parameter estimation were varied. Both uncontaminated and contaminated data were analyzed. The findings indicate that false fixations, especially of intertrial variability parameters, can result in more precise overall parameter recovery. In particular for less than 1000 trials, the restricted models mostly outperform the full model.

Saturday, 11:10
Courville & Montmorency

A model-based neuroscience approach to investigating the role of interactions between brain regions over the course of decision making Marieke K van Vugt, *University of Groningen, Netherlands, The*, Marijke Beulen, *University of Groningen, Netherlands, The*, Simon Houtman, *University of Groningen, Netherlands, The* ■ To date, people have mostly used computational models of cognition to explain what the function is of a certain area of the brain. This topography-based approach ignores how the information flow posited by these models could be implemented by the brain. Yet we can measure such interactions with EEG, where communication between brain regions thought to be reflected in synchronization of EEG oscillations. We have previously demonstrated that a cognitive model of the attentional blink could make predictions about how strong the synchronization should be between brain regions at specific moments in time. For example, specific increases in synchronization when the perceived stimulus information is being compared to a target representation in declarative memory are accompanied by corresponding increases in right parietal-occipital synchronization. Extending this approach to accumulator models of decision making, we examined how the information enters the accumulation process, and how the accumulated information is transformed into a motor command. We show how early in a perceptual decision making task, synchronization is restricted to stimulus regions, while later in the task it primarily reflects motor regions. These findings help to map the whole-brain network involved in (perceptual) decision making.

Saturday, 11:30
Courville & Montmorency

Using LBA to model RTs collected in the GRT paradigm Noah Haskell Silbert, *University of Cincinnati, United States of America*, Joseph W. Houpt, *Wright State University, United States of America* ■ General recognition theory (GRT) provides a powerful framework for modeling interactions between perceptual dimensions in identification-confusion data. The linear ballistic accumulator (LBA) model provides powerful methods for analyzing multi-choice (2+) response time (RT) data as a function of evidence accumulation and response thresholds. We extend (static) GRT to the domain of RTs by fitting LBA models to RTs collected in two auditory GRT experiments. Although the mapping between the constructs of GRT (e.g., perceptual separability, perceptual independence) and the components of the LBA (e.g., drift rates, response thresholds) is complex, the dimensional interactions defined in GRT can be indirectly addressed in the LBA framework by testing for invariance of LBA parameters across appropriate subsets of the data. The present work focuses on correspondences between (invariance of) parameters in LBA and perceptual separability and independence in GRT.

Saturday, 11:50
Courville & Montmorency

Individual differences in working memory capacity and workload capacity Ju-Chi Yu, *Department of psychology, National Cheng Kung University*, Ting-Yun Chang, *Department of psychology, National Cheng Kung University*, Cheng-Ta Yang, *Department of psychology, National Cheng Kung University* ■ We investigated the relationship between working memory capacity (WMC) and workload capacity (WLC). Each participant performed a complex span task to measure his/her WMC and three different redundant-target detection tasks in which the redundant targets were two object's visual features (e.g., color and shape), two spatially independent dots, or two signals from different modalities (e.g., visual and auditory) to measure his/her WLC. 57 participants were instructed to make a go/no-go response in Experiment 1 and 71 participants were instructed to make a 2AFC response in Experiment 2. We used the reaction time data of each task to compute the nonparametric (systems factorial technology; SFT) and parametric (the linear ballistic accumulator; LBA) measures of WLC. Results showed that the participants high in WMC (the top 20

Saturday, 12:10
Courville & Montmorency

Modeling a modified visual search with racing diffusion processes Fabio Leite, *The Ohio State University at Lima, United States of America* ■ Following Leite and Ratcliff (2010), I studied what happens with the decision and non-decision processes as the number of alternatives (in simple perceptual decisions) increases. Specifically, response time and accuracy data were collected from a multiple-location search paradigm in which stimulus difficulty and probability of the response alternatives were varied (across nine and eleven participants, respectively) along with number of response alternatives (viz., two, four, and eight locations). I

will discuss the results from fitting sequentialÂsampling models using racing diffusion processes to the data. Key observations were that the degree of caution increased as the number of alternatives increased (consistent with previous findings), nondecision encoding time did not increase monotonically with number of alternatives (as it could be inferred based on previous paradigms), that a parameter in the model could capture the effects of attentional neglect on unavailable alternatives (in the cases of two and four alternatives), and that input strength parameters captured the effects of both difficulty and probability manipulations, suggesting these parameters can accommodate attentional adjustments as well as evidence quality. I will also discuss both the observed failures to fit the accuracy data precisely in some instances involving multiple locations or two locations amid prior-probability manipulations and the choice of which model parameters would vary across blocks with different number of available locations. The nondecisional variable, for example, had no known physiological basis for varying, whereas the quality of the input from each location in the stimulus, the strength of the lateral inhibition across locations, the decision threshold, and the noise in the accumulation process had valid psychological arguments for being free to vary in the model.

Regular Session 3

Chair: Leslie Blaha

Saturday, 14:00
Palais

Clustering to Dimensionality, Part 1: A Simplicial Complex Approach to Structure Brett A. Jefferson, *Indiana University, United States of America*, Leslie M. Blaha, *711th Human Performance Wing, US Air Force Research Laboratory* ■ We present a topological approach to modeling perceptual space that enables dimensionality to be derived from the clustering of psychological proximity data. In this first part, we explore one concept from mathematics that can be applied to disparate data about human perception: the simplicial complex. Simplicial complexes are objects that provide us with a flexible framework for embedding perceived objects, discovering unseen structure, and explaining high dimensional relationships. Generally, a simplicial complex is a mapping from a set of points to the convex hull of the set. A simplicial complex serves to highlight similarity between points, akin to clustering techniques; it carries clustering information and has dimensional flexibility, and if you begin with a metric space, it is metric preserving. Importantly, naturally occurring phenomena such as asymmetries and metric violations pose no problem for our approach, so we do not need to assume a metric space to derive a simplicial complex for data. This novel analysis technique is readily matched against other exploratory data analysis methods. In our explication, we will lay out the theoretical implications of applying a simplicial complex structure to psychological proximity data (namely, similarity ratings). Next, we present the results from the analysis of some classic psychology datasets (Helm, 1964; Wish 1971; Ekman 1954). We illustrate that simplicial complexes re-create the results of a hierarchical clustering analysis, and then offer deeper insights about structure through the analysis of connected components. These results provide evidence that our approach

to data analysis yields a more rich and satisfying grasp on proximity data over clustering methods and multidimensional scaling. Simplicial complexes, while useful as an individual analytic tool, set us up to study other interesting structure in proximity space that otherwise would be lost. We delve into these analyses in Part 2.

Saturday, 14:20
Palais

Clustering to Dimensionality, Part 2: Uncovering Hidden Patterns in Similarity Ratings Leslie M. Blaha, *Air Force Research Laboratory, United States of America*, Brett A. Jefferson, *Department of Psychological and Brain Sciences, Indiana University, Bloomington, Indiana* ■ We present a topological approach to modeling perceptual space that enables dimensionality to be derived from the clustering of psychological proximity data. In this second part, we derive the persistent homology of perceptual proximity data in order to understand the complex multidimensional structures that are represented in similarity ratings. Following the derivation of a simplicial complex on a set of data, we construct a sequence of vector spaces in which the basis elements (generators) of a given vector space are n-dimensional cyclic structures within the simplicial complex. The collection of these vector spaces is homology. Akin to traditional multidimensional scaling techniques, persistent homology derives the dimensionality from data. However, rather than settling on a single dimensional choice (e.g. a one or two-dimensional solution), homology identifies structure simultaneously on multiple dimensions. We illustrate this with the classic color proximity datasets from Helm (1964), in which we find homological structure in 0-space (connected components), 1-space (2-dimensional structure, or a circle), and even higher structure in 2-space and even 3-space (spheres in 3 and 4 dimensions). This suggests that normal color perception is supported by the traditional two-dimensional multidimensional color representation (i.e. a color circle) but also by some complex perceptual relationships in higher dimensions than are traditionally concluded.

Saturday, 14:40
Palais

Learning transformations relevant to similarity Steven Langsford, *Adelaide University, Australia*, Daniel J. Navarro, *Adelaide University, Australia*, Amy F. Perfors, *Adelaide University, Australia*, Andrew T. Hendrickson, *Adelaide University, Australia* ■ The ability to compare items to determine how similar they are is a basic cognitive process invoked as a primitive in a wide range of cognitive theories, including development and learning (Carey, 2009), memory (Raaijmakers & Shiffrin,1980), categorization (Medin & Schaffer, 1978), and perception (Humphrey,1924), among others. However the mechanisms that underlie human similarity judgement are still unclear, and a number of substantially different approaches have been proposed in the literature (see Goldstone, Day, & Son, 2010 for a review). One proposed mechanism to judge similarity is transformational similarity (Hahn, Chater, and Richardson 2003), in which the similarity between two entities is determined by measuring the edit distance from one to the other given a basic set of transformations. The ability of transformational accounts of similarity to explain human behaviour depends critically on which transformations are included in the set of

possible transformations (Larkey & Markman, 2005; Hodgetts, Hahn, & Chater, 2009). Previous work in this area has arbitrarily determined which transformations are included in the set of possible transformations. This study attempts to address this issue by empirically testing how people select, use, and learn transformations. In a series of experiments using forced-choice similarity judgements, individual transformations are contrasted with each other to determine the variability and size of their impact on similarity judgements. In addition, we assess the degree to which the impact of transformations is constant through time by measuring the degree to which similarity judgements are altered through repeated exposure to a particular transformation. The results presented here constitute a first step towards an empirically grounded account of transformation learning, the full specification of which would address criticisms of transformational similarity by explicitly modelling an important source of unquantified flexibility, exposing these models to stronger tests. The implications of this work for transformational models of similarity will be addressed.

Saturday, 15:00
Palais

Learning functions actively- A Bayesian Optimal Design approach Eric Schulz, *University College London, United Kingdom*, Maarten Speekenbrink, *University College London, United Kingdom* ■ How do and should agents actively acquire information about their environment? Past experiments have mostly addressed this question in the context of concept learning and the inference of causal structure. The present research focusses on how humans acquire functional representations in systems where they can manipulate an input, observe an output and -over time- learn about the underlying function mapping input to output. The experiments are all created within the same experimental paradigm, called "planet mushroom", that offers an easily changeable base for testing different input-output-relationships within an intuitively understandable domain. By using a Bayesian Optimal Design approach (BOD), we first compare human learning with optimal learning, designed via classical optimal experimental design calculations, in linear, quadratic and n-degree polynomial cases. Going on, we will compare human active learning within the domain of continuous input and binary outputs with the help of a particle filter-based approach for BODs within the domain of logistic regression. For the multi-dimensional case, we will first show one scenario where participants have to explore and exploit a 2-dimensional grid containing geometrical shapes within a situation, where the optimal Bayesian solution is still analytically tractable. Using Gaussian Process Optimal Design (GPOD), the active learning approach is then generalized to a bandit setting where the goal is to both learn about and finally exploit a landscape of normally distributed outputs. Situations and causing factors for close to optimal active learning behavior will be demonstrated. Limitations and future steps will be discussed.

Saturday, 15:20
Palais

Restless bandits: Exploring and exploiting in a changing environment Maarten Speekenbrink, *University College London, United Kingdom*, Emmanouil Konstantinidis, *University*

College London, United Kingdom ■ Rather than reasoning about fully described decision problems, we often have to learn to make decisions by taking actions and experiencing their outcomes. In such situations, there is a dilemma between choosing alternatives that we believe will provide good outcomes ("exploiting") and choosing alternatives in order to learn more about their outcomes ("exploring"). How to balance exploration and exploitation is a fundamental issue in reinforcement learning and especially pertinent in volatile environments where the action-outcome contingencies change over time. We present two studies investigating how people learn and make decisions in "restless bandit" tasks involving repeated choices between multiple alternatives with changing rewards. Comparing a large number of learning and decision rules, we show that a substantial proportion of people appear to act as reflective Bayesian learners who choose actions according to the probability that these provide a higher utility than the other actions. This form of probability matching (also known as "Thompson sampling") is shown to be particularly advantageous in the volatile environments studied here.

Regular Session 4

Chair: Robin Thomas

Saturday, 14:00
Courville & Montmorency

Decisions about decisions in the GRT can be tough to come by
Robin Thomas, *Miami University, United States of America*, Noah Haskell Silbert, *University of Cincinnati* ■ We discuss recent theoretical work within the general recognition theory framework that explores what we can and cannot learn about decision processes using identification-confusions from the feature complete factorial design experiment. Specifically, though the constructs regarding the separability of perceptual attributes and decisions regarding their identity are logically independent, they cannot be separately identified empirically. Useful indices regarding properties associated with response concepts can still be obtained from this paradigm including traditional concepts of bias and optimality. For the latter, we indicate what the relationship is between separability of decisions and optimal responding in a Bayesian sense and note the invariance of the resulting decision bound geometry even in the face of changes in stimulus probability and payoffs. This may be a useful property to look for if one is attempting to establish optimal response selection. We conclude with some general suggestions and concerns for future development.

Saturday, 14:20
Courville & Montmorency

Subset System: Mathematical Foundation of Relational Structures
Jun Zhang, *University of Michigan, United States of America*, Yitong Sun, *University of Michigan, United States of America* ■ A "subset system" (V, E) refers to an arbitrary collection E of subsets of a set V. We show that any subset system induces a preorder (reflexive and transitive) and a tolerance (reflexive and symmetric) binary relation on elements of V based on, respectively, inclusion and non-zero intersection relationships between sub-collections E(v), which is a subset of E, containing the respective elements v of V. The pre-order and tolerance relations, in turn, each induce an upper

and lower approximation of any subset of V. This allows us to define closure and interior operators, as well as notions of neighborhood, separability, base, etc in much weaker setting than other algebraic structures, such as lattice and topology. We also discuss how subset systems provide a versatile modeling framework and language for handling objects, features, and contexts.

Saturday, 14:40
Courville & Montmorency

Curiosity, Information Gaps, and the Utility of Knowledge Russell Golman, *Carnegie Mellon University, United States of America*, George Loewenstein, *Carnegie Mellon University, United States of America* ■ We propose an integrated theoretical framework that captures the diverse motives driving decisions to obtain or avoid information. Beyond the conventional desire for information as an input to decision making, people are driven by curiosity, which is a desire for knowledge for its own sake, even in the absence of material benefits, and people are additionally motivated to seek out information about issues they like thinking about and avoid information about issues they do not like thinking about (an "ostrich effect"). The traditional expected utility framework is enriched with the insights that knowledge has valence, that ceteris paribus people want to fill in information gaps, and that, beyond contributing to knowledge, information affects the focus of attention.

Saturday, 15:00
Courville & Montmorency

The Dynamics of Bidirectional Thought Sudeep Bhatia, *University of Warwick, United Kingdom* ■ Bidirectionality is an important property of high-level cognition. The available evidence in a judgment task, for example, does not only determine people's conclusions. The use of this evidence is itself affected by whether it supports the conclusions that are being considered. This relationship is dynamic, and the use of evidence can change over the time course of judgment, so as to cohere with emerging beliefs. Theoretical approaches to studying high-level bidirectional cognition generally involve constraint-satisfaction, a form of computation that is most commonly modeled using recurrent neural networks. Most of these networks are highly complex and, as a result, theoretically opaque. Analytical results regarding their emergent dynamics and final stable states do not exist, and the key properties of bidirectional thought are yet to be fully understood. We propose the bidirectional associative memory (BAM) network as a tractable framework for studying bidirectional thought. BAM is a two-layered neural network with symmetric bipolar connections and binary activation functions. It was initially introduced by Kosko (1988), and has since then been successfully applied to pattern matching, classification and related practical tasks. In this paper, we analyze the dynamics of the BAM network in order to develop theoretical insights regarding the effects of bidirectionality on human cognition. Overall, we find that the BAM network is able to mimic the key properties of many existing models of reasoning and decision making. This allows it to provide a unitary explanation for a range of well-known behavioral phenomena, including coherence shifts in reasoning, confirmatory search biases, and anchoring effects, where

bidirectional relationships exist between evidence and conclusions; effects involving assessments of similarity and of inductive strength, where bidirectional relationships exist between features and categories; and reference point effects and coherence shifts in preferential choice, where bidirectional relationships exist between attributes and choice alternatives. Our results show that the BAM framework provides a simple but structured approach to studying bidirectionality in high-level cognition. It illustrates the close connections between a number of diverse psychological domains, and shows how findings in these domains, as well as many existing explanations for these findings, are related to each other though bidirectionality.

Saturday, 15:20
Courville & Montmorency

Yet Another Stochastic Convergence Analysis of Residual Gradient Temporal Difference and Q Learning
Richard Golden, *University of Texas at Dallas, United States of America* ■ The goal of this paper is to introduce a classical Stochastic Approximation Theorem to support stochastic convergence analysis of discrete-time adaptive learning systems in both finite-state and continuous-state spaces whose assumptions, proof, and conclusions are relatively transparent. The classical Rescorla-Wagner model (or equivalently Widrow-Hoff model as noted by Sutton and Barto (1981, Psychological Review)) of adaptive learning has been applied to modeling a wide range of behavioral, cognitive, and neural phenomena. In addition, theories of Temporal Difference learning have in recent decades played an influential role in influencing theories of adaptive neural control systems (e.g., Niv, 2009, Journal of Mathematical Psychology). Such adaptive neural control systems operate in "active" statistical environments where the learning machine's behavior actually modifies the characteristics of it's statistical environment during learning. In this talk, I introduce a stochastic approximation theorem for stochastic convergence analysis of adaptive learning algorithms based upon classical arguments (e.g., Blum, 1954; Kushner, 2010). This particular Stochastic Approximation Theorem is applicable to both discrete-state and continuous state Markov Chain statistical environments in which environmental characteristics are possibly functionally dependent on the learning machine's behavior. The benefits of this theorem are that the assumptions and conclusions are easily interpretable and broadly applicable yet the theorem is broadly applicable. After stating the assumptions and conclusions of the theorem, the proof of the theorem is briefly sketched. Objective functions for Hebbian learning, Widrow-Hoff learning, residual gradient temporal difference learning, and residual gradient Q-learning are then constructed. Using these objective functions, the new Stochastic Approximation Theorem can be applied in a straightforward manner. Moreover, by viewing such algorithms as minimizing an objective function, such algorithms are provided with semantically interpretable computational goals. Specifically, such learning algorithms are interpretable as von-Neumann-Morgenstern type rational learning machines.

Regular Session 5

Chair: Peter Pantelis

Saturday, 16:00
Palais

Using autonomous virtual agents for a true psychophysics of theory of mind
Peter C. Pantelis, *Indiana University, United States of America*, Timothy Gerstner, *Rutgers University, United States of America*, Kevin Sanik, *Rutgers University, United States of America*, Ari Weinstein, *Rutgers University, United States of America*, Steven A. Cholewiak, *Rutgers University, United States of America*, Gaurav Kharkwal, *Rutgers University, United States of America*, Chia-Chien Wu, *Rutgers University, United States of America*, Jacob Feldman, *Rutgers University, United States of America*, Daniel P. Kennedy, *Indiana University, United States of America* ■ The ability to relate another agent's actions to its mental states (e.g., goals, beliefs, or intentions) is critical for successful social interaction and defines a functional "theory of mind." To study this ability rigorously, we employ an experimental paradigm in which we operationalize a "mind" as the autonomous computer program underlying a virtual agent's behavior, and define accurate "theory of mind" as an experimental subject's correct inferences about the generative program of an observed agent. The experimenter can manipulate quantitative or qualitative aspects of virtual agents' computer programs and then measure inferences subjects make about these agents' "mental" states. We previously developed this paradigm within a 2-dimensional computer simulation environment, populated with virtual agents with simulated perception, memory, and decision-making (Pantelis et al., 2014). These virtual agents are depicted quite minimally as moving triangles interacting within a sparse environment (similar in appearance to classic stimuli used in Heider & Simmel, 1944), but importantly, their behaviors are determined by their respective internal computer programs in this dynamic multi-agent simulation. In the present study, each agent's momentary behavior is modulated by the particular "goal state" it is in, and we examine how manipulating certain qualities of an agent's simulated decision making strategy influences experimental subjects' ability to infer the agent's state. In particular, we endow some agents with awareness of the goal states of other agents (i.e., the simulated ability to "mentalize") and the capacity to then use this information explicitly in their decision making. When tasked with inferring the continually-changing, underlying goal state of these agents on a moment-to-moment basis, subjects are more accurate when judging agents that use this ability to mentalize than other agents that do not explicitly conditionalize their behavior on others' goal states. This effect is present from the first trial and its magnitude does not appear to change as a result of learning across trials. We argue that this pattern of results reflects subjects' expectation of mutual rationality among agents—an intuition they bring to the experiment and apply to interpreting the behavior of observed agents in these dynamic scenes.

Saturday, 16:20
Palais

A Bayesian Approach to the Multiple-Label Assignment Problem for Text Documents
Garren Robert Joseph Gaut, *University of California Irvine, United States of America*, Mark Steyvers, *University of California Irvine, United States of America*, David Atkins, *University of Washington, United States of America*, Zac Imel, *University of Utah, United*

States of America, PADHRAIC SMYTH, *University of California Irvine, United States of America* ■ The classification and categorization of complex items such as documents and natural scenes often involve the problem of assigning multiple content labels to a single item. For instance, when describing a medieval fairy tale about a fight between a knight and dragon, possible labels might include 'knight', 'sword', or 'horse'. Labelers must find a set of labels that most accurately conveys a description of each item. In our fairy tale example, a label 'knight' or 'dragon' would accurately convey the content of the story, whereas a label 'horse' given for a specific descriptive sentence, would be misleading about general content. In this work, we develop a computational model for the multiple-label assignment problem. The model is based on the Labeled Dirichlet Allocation Model (labeled LDA), a machine learning approach for multiple-label document classification. We apply the model on a large collection of transcripts from psychotherapy sessions between patients and therapists. Each session is associated with labels related to the subject of conversation as well as the symptoms displayed by the patient. We model the generation of a transcript as a probabilistic process, where each label is a multinomial distribution over words and each session is a multinomial distribution over labels assigned to that session. Individual words of the dialogue are generated by first sampling a label from the session distribution and then sampling a word from the label distribution. We assess the predictive accuracy of the model in assigning labels to new sessions. We also assess the ability of the model to find (local) talk turns in the dialogue that are representative of the (global) session level label assignments. We demonstrate that while performance varies between labels, for a few labels, the correlations between the model's and human ratings of representativeness come close to the upper bound of human reliability.

Saturday, 16:40
Palais

The dynamic changes of the processing architecture in cued detection
CHENG-TA YANG, *National Cheng Kung University, Taiwan, Republic of China*, TING-YUN CHANG, *National Cheng Kung University, Taiwan, Republic of China* ■ Recently, we demonstrated that the processing architecture can vary according to the cue validity in cued detection (Yang, Little, & Hsu, submitted). When an exogenous cue 100% predicted the target location, participants serially and exclusively processed the cued location first. In contrast, when a cue was uninformative (50% valid), participants adopted a parallel processing strategy. Following this study, we aimed to test whether a shift from serial to parallel processing can be observed in an AND task. In this task, a correct decision requires the participants to process both target locations, which may encourage the participants to adopt a parallel processing strategy regardless of the cue validity. We were also interested in the dynamic changes of the processing architecture from one cue condition to the other. Our preliminary findings showed that participants adopted an exhaustive rule in both cue conditions. More interestingly, we found that both the presentation order of the cue conditions and practice affected the changes of the processing architecture. For the participants who first completed the 50% condition, they shifted their strategies from parallel processing to serial processing progres-

sively. Under the reverse circumstance, individual differences were observed: one participant insisted to process target locations serially regardless of the cue validity, and the other two participants shifted from serial processing to parallel processing. Taken together, "AND" task requirements affected the stopping rule rather than the processing architecture. The observation of the dynamic changes of the processing architecture highlights the flexibility and individual differences of a decision mechanism.

Saturday, 17:00
Palais

Modelling human performance on the vertex cover problem
Sarah Elizabeth Carruthers, *University of Victoria, Canada* ■ Understanding what strategies explain human performance on computationally hard problems is an interesting and worthwhile challenge. Studies to date have found that humans are capable of finding close to optimal solutions to instances of NP-Complete problems like the Euclidean traveling salesperson problem (E-TSP) and minimum vertex cover. These studies have focused on the optimization version of these (and other) problems, in which participants are asked to find a "best" solution. The search version of a problem, in contrast, asks for solution that matches a quantifiable goal. This difference has important implications in terms of participants' ability to generate an internal representation of the problem that can be consistent with the given task. In this work, we consider the vertex cover problem, which asks, given a graph consisting of vertices V and edges E, for a cover for the graph. A cover is subset of vertices, U, such that every edge in E is incident to at least one vertex in U. We propose a simple probabilistic model that explores possible strategies to explain performance on the optimization and search version of the vertex cover problem. Four simple strategies are identified that are sufficient to explain performance on the majority of solutions of the optimization version of vertex cover, both in terms of solution quality and the number of steps required. This model, as predicted, is not sufficient to explain performance on the search version of the problem, but serves as the basis for an iterative search model that very closely matches participants' solutions in terms of solution quality.

Regular Session 6

Chair: Hans Colonius

Saturday, 16:00
Courville & Montmorency

Stochastic orders for comparing reaction time distributions
Hans Colonius, *University of Oldenburg, Germany* ■ The benefits of comparing reaction time (RT) distributions with respect to measures other than the mean or median has been recognized since long. However, results on comparing and ordering RT distributions with respect to response variability are still somewhat scarce. Here we present some results on variability orders based on the quantile function extending previous work (Townsend & Colonius 2005 Psychometrika), on separating measures of skewness and kurtosis for asymmetric distributions, and on stochastic dependence via variability.

Saturday, 16:20
Courville & Montmorency

The Memory Tesseract: Distributed MINERVA and the Unification of Memory Matthew Alexander Kelly, *Carleton University, Canada*, Douglas Mewhort, *Queen's University, Canada*, Robert West, *Carleton University, Canada* ■ Simulation has led to parsimonious theories of memory, but at a cost of a profusion of competing models. However, simulation models share many characteristics indicating wide agreement about the mathematics of how memory works. Here, we argue that many of the dominant memory models in the literature can be understood in terms of a single neurally plausible memory framework. This effort at unification is based on the MINERVA 2 model. We prove that MINERVA 2 (Hintzman, 1984), a widely-used model of biological long-term memory, is mathematically equivalent to an auto-associative memory implemented as a fourth order tensor, i.e., a 'memory tesseract'. We further propose an alternative implementation of MINERVA 2 as a holographic lateral inhibition network. Our work clarifies the relationship between MINERVA 2 and other memory models, and shows that MINERVA 2 and derivative models can be neurally implemented and scaled-up to long-term learning tasks: 1. Viewing MINERVA 2 and its variants (collectively, MINERVA models) as a fourth order tensor clarifies the relationship between MINERVA and third order, second order (i.e., matrix), and compressed tensor (i.e., holographic vector) memory models, allowing us to move toward a unified understanding of memory. 2. Whereas MINERVA as standardly implemented grows with each additional episode stored, the memory tesseract implementation is a data structure of a fixed size and as such can be scaled up to model arbitrarily long term learning at no cost to efficiency, broadening the scope of tasks to which MINERVA can be successfully applied and allowing for unification with models of semantic learning, such as BEAGLE (Jones & Mewhort, 2007). 3. A naïve neural interpretation of MINERVA might suggest that a new neuron is grown for each new experience, corresponding to the addition of another row to MINERVA's memory table. Understood as a memory tesseract, MINERVA is fully distributed across neural connectivity, and new memories can be added by changing the connectivity without requiring additional neural resources. The memory tesseract, or its holographic approximation could be straightforwardly implemented as a realistic neural model using, for example, Eliasmith's (2013) neural engineering framework, a system for implementing vector models in spiking neurons.

Saturday, 16:40
Courville & Montmorency

Building a Learning Space on a Given Domain Jean-Paul Doignon, *Université Libre de Bruxelles, Belgium* ■ A learning space encodes all the possible states of knowledge in a body of information as subsets of a domain. We investigate the practical problem of building a learning space on a given domain from partial information collected either from experts or from data of student assessments. Our solution differs from the one of Eppstein, Falmagne and Uzun (2009); it relies on some properties of the collection of all the learning spaces on the domain. We take avantage of the fact that learning spaces are just the duals of antimatroids, and rely on results of Edelman and Jamison (1985) and Caspard and

Monjardet (2004) about the latter. This is (in part) joint work with Jean-Claude Falmagne, University of California, Irvine.

Saturday, 17:00
Courville & Montmorency

Modeling and design of optimal switch keyboards Gregory Francis, *Purdue University, United States of America*, Xiao Cosmo Zhang, *Purdue University, United States of America* ■ People with motor control difficulties often communicate with a computer by using a switch keyboard where user responses guide a scanning cursor to type text elements. This kind of keyboard requires a trade-off between typing speed and accuracy. Important factors in this trade-off include the cursor's speed, the path of the scanning cursor, and the layout of characters along that path. We show how to optimize these properties of a switch keyboard by casting the design problem as a mixed integer programming (MIP) problem. Identifying an optimal design requires a model of the probability of an entry error. We developed such a model based on data gathered from well-practiced subjects using various types of switch keyboards. We show that the MIP algorithm produces optimal assignments of characters to locations along the cursor path. We also show how to extend the design process to identify the fastest cursor speed that satisfies a desired accuracy rate. Finally, we show how to further extend the design process to consider different types of cursor paths. We show that for the text used in this study, there is an optimal cursor path that trades-off the speed of the cursor against the number of required user-interactions. Each interaction risks an error, but it also reduces the number of cursor steps. The resulting algorithms are valuable for identifying optimal designs in many situations, and can be further elaborated to consider predictive keyboards and different types of input mechanisms.

Regular Session 7

Chair: Sebastien Helie

Sunday, 9:00
Palais

Automatic sequence production in the brain: A neurocomputational model Sebastien Helie, *Purdue University*, Jessica Roeder, *University of California, Santa Barbara*, Lauren Vucovich, *University of California, Santa Barbara*, Dennis Runger, *University of Southern California*, F. Gregory Ashby, *University of California, Santa Barbara* ■ Most human and non-human animal actions unfold in time (e.g., walking, talking) and can be understood as a sequence of movements or cognitive activities. Moreover, most of these actions are automatic and repeated daily during the course of the animal's life. Yet, relatively little is known about the neurobiology of automatic sequence production. Past research suggests a gradual transfer from the associative striatum to the sensorimotor striatum, but a number of more recent studies challenge this role of the basal ganglia in automatic sequence production. In this presentation, we propose a new neurocomputational model of automatic sequence production in which the main role of the basal ganglia is to train cortical-cortical connections within the premotor areas that are responsible for automatic sequence production. The new model is used to simulate four different data sets from human and non-human animals, including (1) behavioral data (e.g.,

response times), (2) electrophysiology data (e.g., single-neuron recordings), (3) macrostructure data (e.g., transcranial magnetic stimulation), and (4) neurological circuit data (e.g., inactivation studies). We conclude with a discussion of a possible new role for the basal ganglia in automaticity.

Sunday, 9:20
Palais

Modeling Nuances of the Spacing Effect Tiffany S. Jastrzembski, *Air Force Research Laboratory, United States of America*, Michael A. Krusmark, *L3 Communications at the Air Force Research Laboratory*, Yun Tang, *Ohio State University*, Kevin A. Gluck, *Air Force Research Laboratory, United States of America*, Glenn Gunzelmann, *Air Force Research Laboratory, United States of America*, Matthew M Walsh, *National Research Council Postdoctoral Associateship - Air Force Research Laboratory*, Hans P.A. Van Dongen, *Washington State University* ■ One hundred thirty years after the first systematic studies on human memory (Ebbinghaus, 1885), we remain interested in improving our understanding of key empirical phenomena through higher fidelity modeling and more nuanced experimentation. An example of one phenomenon of interest is the spacing effect, which reveals that increased temporal lag between study episodes often improves retention of material, enhancing performance on later tests (see Janiszewski et al., 2003). Most prior research examined effects of spacing in similar ways, meaning brief experimental timeframes with only a few data points available for each participant, short time lags between practice repetitions (Cepeda et al., 2006), and little variation in the implementation of massed and distributed practice. Recent efforts to apply models of the spacing effect to real-world learning and training settings (Pavlik, 2008; Jastrzembski et al., 2009; Lindsay et al., 2013) suggest a need to critically examine this human memory phenomenon more fully and to test such models across a broader range of study and practice schedules than have been used in the past. In the current investigation, we focus our attention on one model of the spacing effect, the predictive performance equation (PPE). We evaluate its predictive validity in an experiment investigating patterns of learning for paired associates across a timeframe of three days, and across a range of massed, distributed, and intermediary practice schedules all resulting in 20 practice opportunities for each pair. These schedules relatively mass practice near the beginning, relatively mass practice near the end, evenly distribute practice over 2 to 10 sessions, ramp up training, or taper down training across the duration of the experiment. Our findings reveal that PPE achieves much higher predictive validity when practice is spaced over days than when practice is tightly massed within a single day. We will present and discuss these results from the perspective of explanatory mechanisms in the mathematical model. Capturing spacing effect scheduling nuances with appropriate models will be crucial, as real-world applications must rely on valid predictions to be of any use. More thorough examinations of model predictions across a range of schedules are necessary to evolve cognitive theory of the spacing effect.

Sunday, 9:40
Palais

A Bayesian approach for estimating the probability of trigger failures in the stop-signal paradigm

Dora Matzke, *University of Amsterdam, Netherlands, The*, Scott D. Brown, *University of Newcastle, Australia*, Patricia T. Michie, *University of Newcastle, Australia*, Andrew Heathcote, *University of Newcastle, Australia* ■ The cognitive concept of response inhibition is frequently investigated using the stop-signal paradigm. In this paradigm, participants perform a two-choice response time task where, on some of the trials, the primary task is interrupted by a stop signal that instructs participants to withhold their response. Performance in the stop-signal paradigm can be conceptualized as a horse race between two competing processes: a go process that is initiated by the primary task stimulus and a stop process that is triggered by the stop signal. If the go process wins the race, the primary response is executed; if the stop process wins the race, the primary response is inhibited (Logan & Cowan, 1984). Successful response inhibition requires relatively fast stop responses as well as a high probability of triggering the stop process. The horse-race model allows for the estimation of the latency of the stop response, but is unable to reliably identify deficiencies in triggering the stop process. Here we introduce a Bayesian mixture model that addresses this limitation. Our method is based on the recently developed Bayesian parametric approach (Matzke, Dolan, Logan, Brown & Wagenmakers, 2013) and allows researchers to estimate the probability of trigger failures as well as the entire distribution of stopping latencies. We demonstrate the consequences of unaccounted trigger failures for the estimation of stopping latencies and illustrate the use of our approach with a clinical stop-signal data set.

Sunday, 10:00
Palais

A Cognitive Psychometric Model for the Psychodiagnostic Assessment of Memory Related Deficits
Gregory Alexander, *University of California, Irvine, United States of America*, William Batchelder, *University of California, Irvine, United States of America* ■ Clinical tests used for psychodiagnostic purposes, such as the well-known Alzheimer's Disease Assessment Scale, cognitive sub-scale (ADAS-Cog), include a free recall task. The free recall task taps into latent cognitive processes associated with learning and memory components of human cognition, any of which might be impaired with the progression of Alzheimer's disease. A Hidden Markov Model is developed to optimally measure latent cognitive processes used during the free recall task. In return these cognitive measurements give us an insight into which normal cognitive functions are impaired by a medical condition such as mild cognitive dementia. For example, analyzing the behavioral measures obtained from participants, the model shows that mild cognitive impaired patients have deficits in their ability to encode words into the long-term memory, have a diminished capacity in short-term memory, profit less from successful recall from short-term memory, and a greater inability to retain learned items in the long-term memory compared to participants who have cognitive function that is normal for their demographic peer group.

Sunday, 10:20
Palais

The nearly null cognitive effects of relaxation and the stressful problem of

measuring it. Bruce Oddson, *Laurentian University, Canada*, Rizwan Haq, *Laurentian University, Canada* ■ Stress can been showed to impair cognition in a variety of ways. Relaxation provides obvious benefits in that it can remove these impairments. However, much less is known about relaxation in comparison to more neutral states. The topic is pertinent due to interest in the impact of positive emotional states - because these tend to be conflated with relaxation. It is also interesting in its own right as relaxation states have a number of positive attributes. We show that relaxation has a nearly null average effect in change detection and visual search tasks. In each experiment relaxation was induced using a 20 minute period combining binaural beats and instructions; this is compared to an active control group which played sudoku for the same period. There are some interesting measurement programs associated with the characterization of relaxation using a mixture of subjective rating, GSR, and HRV data. In practice the relaxation and control groups demonstrated extensive overlap in relaxation states during cognitive task performance according to each of the available measures. However, carelessly considered, the measures themselves show very little concordance. This suggests, in part, that the relaxation states themselves may have been quite heterogenous with respect to the measures used. It also provides an opportunity to construct a test of the structure of these data streams. In particular, analysis based on random matrix theory should be able to evaluate the extent to which these data are chaotic. We then pose the question of whether or not a test can be constructed to link the number or position of potential attractors to the measured state. The test we offer involves the application of geometric data analysis to a series of features extracted from the GSR and HRV time series. The features are intended to capture the dynamics of control from out analysis. The results are contrasted with the expected results from several plausible models derived from polyvagal theory and in turn used to establish the likelihood of null cognitive effects across a broad range of states.

Sunday, 10:40

Palais

Moderator Effects in Multiple Regression: What Gets Moderated and How? Michael Smithson, *The Australian National University, Australia*, Sheri Kim, *The Australian National University, Australia* ■ In multiple regression, moderator effects traditionally are evaluated exclusively in regard to slopes, and in ANOVA the focus is on moderation of means. However, there is a well-known distinction between moderation of the degree and moderation of the form of a relationship between two variables where degree refers to correlations and form refers to slopes. The standardized regression coefficient may be used to evaluate moderation of the form of the relationship in a "scale-free" sense, and the partial and semi-partial correlations may be used to describe moderation of the degree. For any predictor, X, in a regression model of dependent variable Y , the semi-partial correlation and standardized regression coefficient are moderated by Z equivalently only if the tolerance for X (the squared multiple correlation between the other predictors in the model and X) is unmoderated by Z. Likewise, the the semi-partial and partial correlation coefficients are moderated equivalently only if the squared multiple correlation between the other predictors in the model and Y is

unmoderated by Z. This presentation describes the ways in which these three coefficients may be differently moderated and the results of a simulation study assessing the Type I error accuracy of standard significance tests for determining when non-equivalent moderation effects are present.

Regular Session 8

Chair: Michael David Lee

Sunday, 9:00
Courville & Montmorency

Using Bayesian priors in psychological modeling Michael D. Lee, *UC Irvine, United States of America* ■ Even among proponents of Bayesian methods for making inferences about models and data in psychology, priors are often viewed negatively. They are seen as the one downside among a raft of Bayesian upsides, and in both statistical and modeling settings, the goal of choosing priors is often explicitly one of minimizing their impact on inference. Some of this is right in a narrow set of circumstances, and the rest of it is plain wrong. In general, there is a constructive and vital role for priors in improving our ability to express, apply, and evaluate psychological theories. This talk argues that we need to think about priors differently, and presents some cognitive modeling examples – involving the relationship between IQ and reaction times, and making predictions in a wisdom-of-the-crowd setting – that demonstrate their potential constructive role.

Sunday, 9:20
Courville & Montmorency

A wisdom of crowds approach to predicting categorization structures Irina Danileiko, *University of California, Irvine, United States of America*, Michael D. Lee, *University of California, Irvine, United States of America* ■ People's individual differences in learning category structures may be a result of better learning processes, different levels of knowledge, or attending to different stimulus properties. The "wisdom of the crowd" (WoC) phenomenon benefits from these individual differences by combining participant knowledge into master answers that show faster learning than most individuals over the course of a categorization task. A simple way to combine people's answers in such a task is by accepting the majority answer, or the mode for each stimulus. We examined three categorization task datasets: Kruschke (1993), Lewandowsky's (2011) replication of Shepard, Hovland, Jenkins (1961), and Zeithamova and Maddox (2006). This analysis showed that the mode is an effective WoC aggregation measure. We used Nosofsky's (1986) generalized context model as a cognitive model with individual differences to extract individuals' attention and generalization parameters. We generated novel stimuli and applied the model again using the individual parameter values. This enabled the model to predict the participants' categorization decisions if they had seen these stimuli. The WoC majority answer of these decisions successfully predicted the category structures of the novel stimuli.

Sunday, 9:40
Courville & Montmorency

Bayes Factors for Reinforcement-Learning Models of the Iowa Gambling Task Helen Steingroever, *University of Amsterdam, Netherlands, The*, Ruud Wetzels, *University of Amsterdam, Netherlands, The*, Eric-Jan

Wagenmakers, *University of Amsterdam, Netherlands, The* ■ We present an importance sampling method to compute marginal likelihoods for different reinforcement-learning (RL) models of the Iowa gambling task (IGT). These marginal likelihoods can be used to calculate Bayes factors (BF) quantifying the weight of evidence that the data provide for and against competing RL models. We illustrate this importance sampling method to derive BFs for a set of RL models that embody different assumptions about the learning processes underlying the IGT.

Sunday, 10:00
Courville & Montmorency

Inferring hypothesis spaces from generalization data Sean Tauber, *University of Adelaide, Australia*, Daniel J. Navarro, *University of Adelaide, Australia*, Amy F. Perfors, *University of Adelaide, Australia*, Michael D. Lee, *University of California, Irvine* ■ Although there has been much interest in inferring mental representations from similarity data, there have been no attempts at inferring representations directly from generalization data. We develop an approach in which hypothesis spaces can be inferred from human generalization data. By defining the likelihood function relating human generalization data to a Bayesian generalization model, we are able to infer the most likely hypothesis space(s) humans used to produce the generalization data. One of the advantages is that, unlike with similarity based approaches, we can explore the effect of semantic context on the hypothesis spaces people use when generalizing.

Sunday, 10:20
Courville & Montmorency

Dissociating Top-down and Bottom-up Theories of Autism Spectrum Disorders Using Bayesian Models Joseph L Austerweil, *Brown University, United States of America*, Kirstie Stanworth, *University of Sussex, United Kingdom*, Anna Franklin, *University of Sussex, United Kingdom* ■ We define novel Bayesian models of two cognitive theories of Autism Spectrum Disorders (ASDs) to capture how individuals with ASDs differ from typical individuals when they learn causal relations. People learn causal relations between cues and effects in physical and social domains by integrating how often they have observed the cue and effect together with their domain-specific knowledge about the mechanisms whereby cues generate effects. Prior knowledge allows people to need only a few observations to solve this complex task in both physical (e.g., learn that flipping a switch turns on a particular light) and social (e.g., learn that grabbing a toy from a friend will make the friend cry) domains. The amount of weight given to current evidence when it is integrated with prior beliefs should increase with the strength of evidence, in a manner prescribed by Bayes' rule.

There are many documented social and non-social consequences of ASDs, including effects on learning and the way in which those with ASDs perceive and experience the world around them. Two prominent theories seeking to explain these consequences are a top-down hypothesis, the weak coherence hypothesis, where prior knowledge is underweighted, and a bottom-up hypothesis, the enhanced perceptual functioning hypothesis, where current observations are overweighted. We propose Bayesian models of each theory for the problem of learning a causal relation. The Bayesian models pro-

duce divergent predictions, which we tested in a novel adaptation of the "blicket" detector causal learning paradigm. In our modified version, an object's color is a cue to the prior probability that it is a cause (e.g., 80

Sunday, 10:40
Courville & Montmorency

A Bayesian hierarchical mixture approach to individual differences: Case studies in selective attention and representation in category learning Annelies Bartlema, *KU Leuven, Belgium*, Michael D. Lee, *University of California, Irvine*, Ruud Wetzels, *University of Amsterdam, Netherlands*, Wolf Vanpaemel, *KU Leuven, Belgium* ■ We demonstrate the potential of using a Bayesian hierarchical mixture approach to model individual differences in cognition. Mixture components can be used to identify latent groups of subjects who use different cognitive processes, while hierarchical distributions can be used to capture more minor variation within each group. We apply Bayesian hierarchical mixture methods in two illustrative applications involving category learning. The first focuses on the use of selective attention, which is typically conceived of as a problem of parameter estimation. The second focuses on the use of prototype or exemplars in category representation, a problem that is traditionally tackled from a model selection perspective. Using both previously published and newly collected data, we demonstrate the flexibility and wide applicability of the hierarchical mixture approach to modeling individual differences.

Regular Session 9

Chair: Woojae Kim

Sunday, 14:00
Port-Neuf & Ste-Foy

A Hierarchical Adaptive Approach to the Optimal Design of Experiments Woojae Kim, *Ohio State University, United States of America*, Mark A. Pitt, *Ohio State University, United States of America*, Zhong-Lin Lu, *Ohio State University, United States of America*, Mark Steyvers, *University of California at Irvine, United States of America*, Hairong Gu, *Ohio State University, United States of America*, Jay Myung, *Ohio State University, United States of America* ■ Experimentation is at the core of research in psychology, yet observations can be expensive and time-consuming to acquire. A major interest of researchers is designing experiments that lead to maximal accumulation of information about the phenomenon under study with the fewest possible number of observations. In addressing this challenge, statisticians have developed design optimization methods. This paper introduces a hierarchical Bayes extension of adaptive design optimization that provides a judicious way to exploit two complementary schemes of inference (with past and future data) to achieve even greater accuracy and efficiency in information gain. We demonstrate the method in a simulation experiment in the field of visual perception.

Sunday, 14:20
Port-Neuf & Ste-Foy

Default Bayes Factors for Contingency Tables Tahira Jamil, *University of Amsterdam, The Netherlands*, Alexander Ly, *University of Amsterdam, The Netherlands*, Eric-Jan Wagenmakers, *University of Amsterdam, The Netherlands* ■ The

most common summary measure for inference regarding contingency tables is the p-value. Unfortunately, however, the p-value comes with a number of well-documented drawbacks. As an alternative, the hypothesis of independence in contingency tables can also be tested using Bayes factors. Here we review and discuss different sampling models for contingency tables and rovide the corresponding default Bayes factors (Gunel and Dickey, 1974). We illustrate the properties and advantages of a Bayes factor analysis of contingency tables through simulations and practical examples. We hope this work will motivate psychologists to move away from p-values and adopt a method of hypothesis testing that is rational and coherent.

Sunday, 14:40
Port-Neuf & Ste-Foy

Bayesian Tests to Quantify the Result of a Replication Attempt Josine Verhagen, *University of Amsterdam, Netherlands, The*, Eric-Jan Wagenmakers, *University of Amsterdam, Netherlands, The* ■ Replication attempts are essential to the empirical sciences. Successful replication attempts increase researchers' confidence in the presence of an effect, whereas failed replication attempts induce skepticism and doubt. However, it is often unclear to what extent a replication attempt results in success or failure. To quantify replication outcomes we propose a novel Bayesian replication test that compares the adequacy of two competing hypotheses. The first hypothesis is that of the skeptic and holds that the effect is spurious; this is the null hypothesis that postulates a zero effect size. The second hypothesis is that of the proponent and holds that the effect is consistent with the one found in the original study, an effect that can be quantified by a posterior distribution. Hence, the second hypothesis –the replication hypothesis– is given by the posterior distribution from the original study. The weighted likelihood ratio between H0 and Hr quantifies the evidence that the data provide for replication success and failure. There are several other Bayesian tests that address different but related questions concerning a replication study. These tests pertain to the independent conclusions of the separate experiments, the difference in effect size between the original experiment and the replication attempt, and the overall conclusion based on the pooled results. Together, this suite of Bayesian tests allows a complete formalization of the way in which the result of a replication attempt alters our knowledge of the phenomenon at hand. The use of Bayesian replication tests is illustrated with examples from the literature featuring both t-tests and correlations.

Sunday, 15:00
Port-Neuf & Ste-Foy

Identification of publication bias through models of publication behavior Hongyang Guan, *University of California, Irvine, United States of America*, Joachim Vandekerckhove, *University of California, Irvine, United States of America* ■ Recently, there has been a rising concern in the field of psychology about the reliability of published research findings. Publication bias, or treating positive findings differently from negative findings, is a contributing factor to this concern that has recently been referred to as the "crisis of confidence". The tendency of authors to report, and of journals to publish, only favorable

significant findings is likely inflating the number of reported true effects in the literature. Here, we develop a Bayesian test for the detection of publication bias. We postulate a series of different models for the publication process: 1) a no-bias model, 2) an extreme-bias model, 3) a HARKing bias model, 4) a model with a constant bias parameter, and 5) a model with a bias parameter that depends on observed effect size. We compute Bayesian evidence values for all models, under both assumptions of the existence of a true effect and no effect at all. The models are then compared using Jeffreys weights. We use the obtained weights to mitigate the effects of publication bias and estimate the underlying effect size.

Sunday, 15:20
Port-Neuf & Ste-Foy

Adaptive Design Optimization for Comparing Models of the Spacing Effect Yun Tang, *Ohio State University, United States of America*, Tiffany S. Jastrzembski, *Air Force Research Laboratory*, Michael A. Krusmark, *L-3 Communications*, Kevin A. Gluck, *Air Force Research Laboratory*, Mark A. Pitt, *Ohio State University, United States of America*, Glenn Gunzelmann, *Air Force Research Laboratory* ■ In this study we explore an optimal experimental design approach to discriminate spacing effect models. The spacing effect refers to a pervasive phenomenon that increased temporal lag between study episodes improves retention. By integrating mechanisms for learning, forgetting, and retrieval that are sensitive to the distribution of practice opportunities, Jastrzembski et al. (2008, 2009) have developed a mathematical model, referred to as the Predictive Performance Equation (PPE), which captures the spacing effect in a number of specific learning contexts. In the present study, we investigate two theoretically-distinct variants of PPE in the context of an associative memory task. Maximum likelihood-based and Bayesian-based estimation methods are employed to fit the two model variants to data. We then compare the models using multiple generalizability measures. Results from model analyses show that extant experimental designs of spacing schedules may not be equally informative with regard to estimating and comparing spacing effect models. An adaptive design optimization (ADO) procedure is introduced to find spacing schedules that provide the best opportunity to reveal performance prediction differences between the two model variants. We will present the results of simulations, as well as discuss the potential implications for using ADO in longitudinal experiments.

Regular Session 10

Chair: Jörg Rieskamp

Sunday, 14:00
Courville & Montmorency

A sequential sampling model for explaining perceptual and value-based decisions Gilles Dutilh, *University of Basel, Switzerland*, Jörg Rieskamp, *University of Basel, Switzerland* ■ In the decision making literature, there are two important domains of study that have developed largely in isolation. The one domain studies perceptual choice behavior, where the decision maker aims for a correct decision and there is an outside criterion that determines which decision is correct. The other domain studies preferential or value-based decisions, where the decision maker's goals

are subjective, so that no correct option exists. Despite this difference between the two types of decisions and the relative isolation of the two domains, very similar sequential sampling models have been proposed to describe perceptual and preferential choice behavior. In this study we developed an experimental task that can be presented as either a perceptual or a preferential choice task. We propose a new sequential sampling model that can explain both types of decisions simultaneously. The model assumes that people change their belief about the state of the world when accumulating evidence. This approach offers a formal way to explore the differences between the two types of decisions.

Sunday, 14:20
Courville & Montmorency

Testing Models of Deferred Decision Making Jared Michael Hotaling, *University of Basel, Switzerland*, Jörg Rieskamp, *University of Basel, Switzerland* ■ Deferred decision making (DDM) refers to when an individual collects evidence about two or more risky alternatives and decides when to stop and make a final choice. Real world examples include physicians running tests before diagnosing an illness, or commanders collecting intelligence before taking military action. We conducted a DDM study aimed at investigating how people know when to defer a decision and when to stop sampling and make a choice. Participants could purchase up to twenty independent observations about two mutually exclusive hypotheses before making a final choice. Their goal was to make accurate choices, while minimizing sampling costs. We tested several cognitive models and found that a sequential sampling model (SSM) outperformed others build on heuristic or backward induction frameworks. According to the SSM, individuals make explicit decisions to wait and sample more, and require less evidence to make a final choice over time due to collapsing decision bounds.

Sunday, 14:40
Courville & Montmorency

Modeling joint recognition and source memory confidence ratings: Qualitative misses for bivariate Gaussian and dual-process models Jeffrey J. Starns, *University of Massachusetts Amherst, United States of America* ■ Memory researchers have developed many successful models that separately fit confidence ratings from a recognition task (was this item studied in a previous list?) or a source memory task (e.g., was this item studied with a picture of a male or female face?), but accommodating joint ratings from both tasks is an elusive goal that requires matching a number of challenging data patterns. For example, Receiver Operating Characteristics (ROCs) formed from recognition confidence ratings are linear in z space, whereas source memory ROCs are u-shaped in z space when all of the studied items are analyzed and become linear when analyses are limited to items recognized with high confidence. Our goal was to test the ability of various models to match these patterns along with a newly discovered regularity: recognition memory ROCs have a lower slope in z-space for items that received correct versus incorrect source judgments. Neither a standard bivariate Gaussian signal-detection model nor a bivariate extension of the Yonelinas dual-process model could match all of the

empirical patterns. We developed a version of the bivariate signal-detection model in which source discrimination is bounded at zero for low levels of item strength. The bounded model matched all aspects of the data.

Sunday, 15:00
Courville & Montmorency

A probabilistic model of 3D surface interpretation from line drawings
Seha Kim, *Rutgers University, United States of America*, Manish Singh, *Rutgers University, United States of America*, Jacob Feldman, *Rutgers University, United States of America* ■ The 3D shape depicted by a 2D line drawing, which lacks texture or shading cues, is highly ambiguous and undetermined. Human observers, nevertheless, have the ability to perceive pictorial relief in such drawings, using shape cues from certain contour features, such as junctions and contour curvature. Traditional line drawing studies focused on local junction categorization and logical contour labeling, but generally excluded smooth shapes with internal contours arising from self-occlusion. Moreover, such deterministic models cannot account for the probabilistic quality of human shape judgments, in which 3D structure is more uncertain in some parts of the line drawing than others. We developed a probabilistic model that interprets 3D surface shape from line drawings of smooth objects, using both local and global cues. For a given line drawing, the model estimates a probability distribution over possible 3D surfaces, and assumes that subsequent perceptual decisions about 3D shape are based on these distributions. We created a likelihood model for line drawings conditioned on 3D shape by stochastically generating 3D shapes (assuming a skeletal model from which shapes are "inflated"), projecting these shapes and extracting rim points to create line drawings, and then tabulating features of the resulting line drawings. The model then matches observed line drawings to the resulting line drawings using a combination of local and global features. The matched contours are then used to construct a posterior estimate of local 3D surface structure for points along the contours comprised in the line drawing, as well as for arbitrary points within the interior of the line drawing. In empirical studies, subject made binary judgments of relative depth (near/far) for pairs of points in the interior of line drawings. The results showed systematic variations in uncertainty in surface shape at different points within each drawing. We then used the posterior surface shape estimates drawn from our model to model the human data, including both perceived depth differences as well as variations in uncertainty. Human shape from line drawings can be understood as reflecting a posterior estimate of probable 3D shape that reflects both local and global cues.

Sunday, 15:20
Courville & Montmorency

Exploration and Exploitation: Converging Computational, Physiological, Psychiatric, Genetic, and Consumer-Choice Perspectives
Bradley C. Love, *UCL, United Kingdom* ■ In non-stationary environments, there is a conflict between exploiting currently favored options and gaining information by exploring lesser-known options that in the past have proven less rewarding. Optimal decision-making in such tasks requires considering future states of the environment (i.e., planning) and properly updating beliefs about the

state of the environment after observing outcomes associated with choices. Optimal belief-updating is reflective in that beliefs can change without directly observing environmental change. Balancing and timing exploration and exploitation actions is key to effective dynamic decision making. With several colleagues, I have conducted empirical and computational studies of how people navigate the exploration/exploitation dilemma. Empirical studies in the laboratory indicate that people are reflective and belief-driven, which means, like the ideal actor, that choices are guided by uncertainty as opposed to simply "random". Consistent with the ideal actor, people are sensitive to environmental volatility. A number of studies explore the bases for this behavior. Consistent with the idea that sophisticated decision making requires cognitive resources, participants under cognitive load or suffering from depressive symptom do not show this signature of reflective belief updating. Supporting this interpretation, individuals with genetic variations (COMT Met allele) that promote prefrontal dopamine function are more likely to show reflective behavior when balancing exploration and exploitation. Interestingly, physiological measures track this reflective assessment of uncertainty. Finally, this work is extended to consumer decision making in retail environments in which a vast array of options is available to the decision maker. Similar mechanisms successfully predict consumer choice. One insight from these big-data real-world studies is that exploration and exploitation are best construed as involving temporally extended episodes as opposed to individual decision events.

Regular Session 11

Chair: Adele Diederich

Monday, 9:00
Palais

Sequential sampling model for multiattribute choice alternatives with random attention time and processing order ADELE DIEDERICH, *Jacobs University, Germany*, PETER OSWALD, *Jacobs University, Germany* ■ A sequential sampling model for multiattribute binary choice options assumes a separate sampling process for each attribute. During the deliberation process attention switches from one attribute consideration to the next. The order in which attributes are considered as well for how long each attribute is considered - the attention time - influences the predicted choice probabilities and choice response times. Several probability distributions for the attention time including deterministic, Poisson, binomial, geometric, and uniform with different variances are investigated. Depending on the time and order schedule the model predicts a rich choice probability/choice response time pattern including preference reversals and fast errors. Furthermore, the difference between a finite and infinite decision horizons for the attribute considered last is investigated. For the former case the model predicts a probability $p_0 > 0$ of not deciding within the available time. The underlying stochastic process for each attribute is an Ornstein-Uhlenbeck process approximated by a discrete birth-death process. All predictions are also true for the widely applied Wiener process.

Monday, 9:20
Palais

Validating the Parameters of the Dual-Source Model of Probabilistic Conditional Reasoning Henrik Singmann, *Albert-Ludwigs-Universität Freiburg, Germany*, Karl Christoph Klauer, *Albert-Ludwigs-Universität Freiburg, Germany*, Sieghard Beller, *University of Bergen, Norway* ■ In contrast to popular Bayesian models (e.g., Oaksford & Chater, 2007) which solely incorporate participants' background knowledge the dual-source model of probabilistic conditional reasoning (Klauer, Beller, & Hütter, 2010) assumes that reasoners integrate, via a weighting parameter, the information based on background knowledge, formalized as the conditional probabilities of the conclusions given the premises, with information based on the form of the argument, formalized as the subjective probability with which a certain reasoning form is valid (e.g., "How valid is a Modus Ponens on a probability scale?"). We present two within-subjects selective influence experiments in which we validated the parameters of the dual-source model. In the first experiment we contrasted a conditional with a biconditional rule. Results revealed that manipulating the form in this way only affected the form parameters but not the weighting of the two sources. In a second experiment we manipulated rule credibility via speaker expertise (Stevenson & Over, 2001). Results showed that this manipulation only affected the weight given to the form-based component but did not affect the form parameters. These results provide evidence for the psychological plausibility of the parameters of the dual-source model.

Monday, 9:40
Palais

Comparing models of inductive generalization Andrew T. Hendrickson, *University of Adelaide, Australia*, Amy F. Perfors, *University of Adelaide, Australia*, Daniel J. Navarro, *University of Adelaide, Australia* ■ Inductive generalization to new instances occurs in an array of cognitive tasks including categorization, memory, and learning (Shepard, 1987). Models of Bayesian inductive generalization (Tenenbaum & Griffiths, 2001) explicitly include inference over the types of processes that generate instances (Navarro, Dry & Lee, 2012). A critical type of generative process to these models is strong sampling, in which an instance is generated after selecting its category rather than independently of categories (Tenenbaum, 1997). When Bayesian generalization models include strong sampling in their likelihood functions then they predict an inversion of the usual base rate effect – as a category has more instances new instances are less likely to be assigned to that category. This prediction is in direct opposition to the predictions of standard models of categorization that rely on generalization (for example Nosofsky, 1986; Love & Medin, 1998), which predict (if anything) the opposite: additional category members should widen the generalization curve. Despite their opposing predictions, both kinds of models account for human behavior across a wide range of tasks. In this work we investigate this apparent contradiction. One possibility is that both models are accurate, but for different kinds of situations. Indeed, the experimental methods and materials used to empirically demonstrate the inverse base-rate effect and support models of Bayesian generalization (Xu & Tenenbaum, 2007; Navarro & Perfors, 2010; Navarro, Dry & Lee, 2012) differ in critical ways from classical catego-

rization tasks. These factors include the dimensionality of stimuli, the number of categories, the demands on memory, and the response options. In the current work we explored to what extent the opposing predictions are due to these factors. We then compare the fit of both the Bayesian generalization model and more traditional categorization models to individual data across these tasks. The implications for the role of sampling assumptions in categorization and generalization tasks will be discussed.

Monday, 10:00
Palais

An organizing framework for the comparison of semantic models Timothy N. Rubin, *Indiana University, United States of America*, Jon A. Willits, *Indiana University, United States of America*, Brent Kievit-Kylar, *Indiana University, United States of America*, Michael N. Jones, *Indiana University, United States of America* ■ Distributional models of semantics play an important role in cognitive science. These models use statistical learning to model word meanings from co-occurrences in text corpora. A variety of semantic models have been proposed in the literature, wherein the discussion has focused upon performance differences between models on a particular task. However, semantic models often vary with respect to multiple components (e.g., their normalization or dimensionality-reduction methods), making it difficult to delineate which of components are responsible for observed performance differences. Furthermore, a variety of evaluation methods have been employed for comparing these models, which further complicates model comparison by confounding the different types of relationships between words that one might be interested in. Here, we propose a general framework for organizing the space of semantic models. We illustrate how this framework can be used to understand model comparisons in terms of individual manipulations along separate modeling dimensions. We additionally propose definitions for three different types of word relationships: substitutability, associativity, and categorical-similarity. Using several artificial datasets we show how specific component manipulations within our framework influence a model's ability to pick up on these different types of word relationships.

Monday, 10:20
Palais

Heuristics as special cases of Bayesian inference Paula Parpart, *University College London, United Kingdom*, Matt Jones, *University of Colorado, Boulder, USA*, Bradley C. Love, *University College London, United Kingdom* ■ In the previous judgement and decision making literature, rational inference models (e.g. Bayesian models) have typically been depicted as opposing simple and frugal heuristics (e.g., take-the-best or tallying). The current research demonstrates a novel finding wherein prominent decision heuristics are special cases of Bayesian inference. We developed two new Bayesian learning models based on two popular regularization techniques in machine learning, namely ridge regression (L2) and lasso regression (L1). The penalty terms of these models correspond to Bayesian priors that reflect the necessary environmental structures for tallying or take-the-best to succeed. For example, tallying performs best in an environment where cues are equally weighted. In

contrast, take-the-best thrives in a noncompensatory environmental structure, where each cue can outweigh any combination of lesser valid cues. By means of simulation, we demonstrate that the Bayesian inference models become equivalent to the heuristics when the priors become extreme, i.e., in the limit of an infinite penalty parameter. In a re-analysis of well-studied heuristic datasets that span a wide range of domains we show that our modified Bayesian ridge regression outperforms both tallying and standard linear regression. Similarly, our Bayesian extension of lasso regression outperforms both take-the-best and linear regression. A large simulation study furthermore illustrates the practical convergence of the Bayesian learning models to the heuristics with increasingly extreme priors: convergence is reached when the initial cue weights have developed into perfectly equal (tallying) or noncompensatory (take-the-best) weighting structures. Results demonstrate that both heuristics and standard linear regression are special cases of the Bayesian inference models. This implies that heuristics can be adaptive to certain environments, while being continuously contained within a rational inference model. Thereby a formal link between two traditionally opposing theories of decision making is created. In addition, these findings suggest that sometimes the optimal psychological process for a given environmental structure may lie somewhere in between a heuristic and a more complex, integrative regression approach. These new developments have far-reaching implications with respect to the literature on heuristics and rational inference models, as well as other fields that make use of novel regularization algorithms.

Monday, 10:40
Palais

Using probability judgments to distinguish respondent ability from question difficulty Edgar Merkle, *University of Missouri, United States of America*, Mark Steyvers, *University of California, Irvine*, Barbara Mellers, *University of Pennsylvania*, Philip Tetlock, *University of Pennsylvania* ■ In many experiments and forecasting scenarios, multiple respondents provide probability judgments on multiple questions. In a subset of these scenarios, the probability judgments are reported at different points in time. Ideas from item response theory may be used here to estimate respondent ability and question difficulty, though few models have been developed to directly handle probability judgments. Further, model estimation is more complicated when respondents provide probability judgments at different points in time (because questions often become easier over time). We describe a variant of an item response model that simultaneously estimates ability and difficulty while accounting for the fact that probability judgments are reported at different points in time. Using geopolitical forecasts from a recent tournament, we compare the models' ability and difficulty estimates to traditional measures. We also use the models to examine the dimensionality of forecasting ability.

Regular Session 12

Chair: Ingmar Visser

Monday, 9:00
Courville & Montmorency

The General Linear Ballistic Accumulator Model Ingmar Visser, *University of Amsterdam, Netherlands, The* ■ The

linear ballistic accumulator (LBA) model (Brown & Heathcote, 2008) has proven successfull in modelling response times from experimental data. This paper presents and extension of this model in which the LBA parameters can be modeled with linear effects to accommodate explanatory variables. An R-package has been developed to fit these models using maximum likelihood estimation. The usefulness of this model is illustrated using developmental data from a Flankers task and a numerosity estimation task. Brown, S.D., & Heathcote, A. (2008) The simplest complete model of choice response time: Linear ballistic accumulation. Cognitive Psychology, 57, 153-178.

Monday, 9:20
Courville & Montmorency

Deterministic evidence accumulation models Andrew Terry, *University of Newcastle, Australia*, Avinash Barnwal, *University of Amsterdam, Netherlands*, Scott D. Brown, *University of Amsterdam, Netherlands*, Tony Marley, *University of Victoria, Canada*, Eric-Jan Wagenmakers, *University of Amsterdam, Netherlands*, Andrew Heathcote, *University of Newcastle, Australia* ■ Deterministic accumulation processes that form the core of models such as the LBA (Brown & Heathcote, 2008) and LNR (Heathcote & Love, 2012) are easily applied to a range of simple and complex choice tasks because of accurate and quickly-computed expressions for the density and cumulative distribution functions of accumulator finishing times. We develop a general mathematical framework enabling simple closed-form solutions for deterministic accumulator models assuming decision time is the ratio of a uniform distribution (for the distance from the start of accumulation to a response threshold) and any drift rate distribution that meets conditions related to the truncated moments of that distribution. We present use of this framework in develop three new deterministic accumulator models with lognormal, gamma and Frechet rate drift rate distributions. The properties of these models are explored in benchmark data.

Monday, 9:40
Courville & Montmorency

On making connections between cognitive models and neural data Thomas J. Palmeri, *Vanderbilt University, United States of America*, Akash Umakantha, *Vanderbilt University, United States of America*, Braden A. Purcell, *New York University, United States of America* ■ Recent efforts to jointly model behavioral and neural data have forged exciting new connections between cognitive modeling and cognitive neuroscience. For example, both have converged on accumulation of evidence models as a general theoretical framework for explaining the time course of perceptual decisions. An approach used in one successful line of research has correlated neural measures from fMRI or ERP with parameters of accumulator models fitted to behavioral data. An alternative approach used in some of our past work has evaluated competing models on their quantitative fits to behavioral data and then tested how well the dynamics of accumulation in the model predict the dynamics of neurophysiological recordings. Here, we present recent and ongoing work that further illustrates the strengths and limitations of making inferences about neural mechanisms based on accumulator model fits and predicted model dynamics. Our general approach is to simulate

"data" from various types of accumulator models with known parameters, analyze the behavioral predictions and accumulator dynamics in the same way that behavior or neural measures might be analyzed, and assess how well we can "recover" the known mechanisms that produced the simulated data. For example, we have found that variability in predicted model dynamics of stochastic accumulator models are non-trivially related to the variability in model parameters, parameters of accumulators acting within large ensembles cannot always be quantitatively identified by "measures" of the dynamics of individual accumulators within those ensembles, and parameters of abstract accumulator models can have unanticipated one-to-many mappings to parameters of lower-level spiking neural network models.

Monday, 10:00
Courville & Montmorency

Accumulator models of decision-making under changing information William R Holmes, *University of California Irvine, United States of America*, Jennifer S. Trueblood, *University of California Irvine, United States of America*, Andrew Heathcote, *University of Newcastle, Australia* ■ Decisions are often made in dynamic environments where information changes in time. Diffusion models have accommodated these types of situations by allowing drift rates to change during the course of processing (Ratcliff, 1980; Diederich, 1997). Following this idea, we introduce a multi-stage Linear Ballistic Accumulator model, which allows accumulator drift rates to change in response to changes in stimuli information. We test this model using a dot motion task where the direction of motion changes within trials. We fit the multi-stage LBA model to choice and response time data using hierarchal Bayesian parameter estimation with approximate likelihood methods. We compare different variants of this multi-stage LBA model to the standard LBA to 1) show that the multi-stage versions better account for the data and 2) provide a hypothesis about how the decision process is updated based on the changed information.

Monday, 10:20
Courville & Montmorency

Joint Models for Behavioral and Neural Data Joachim Vandekerckhove, *University of California, Irvine, United States of America*, Michael D. Nunez, *University of California, Irvine, United States of America*, Beth Baribault, *University of California, Irvine, United States of America*, Ramesh Srinivasan, *University of California, Irvine, United States of America* ■ We present a latent variable modeling approach to the joint analysis of behavioral and neural data. The approach relies on defining a fully unobserved structure that determines the covariance between cognitive model parameters and neurophysiological measures. Such measures may be task-dependent ones (to focus on experimental effects) or they may be task-independent (resting state variables to focus on individual differences). The models also allow for the inclusion of external covariates to explain individual differences in addition to experimental design variables. We will present an example data set involving EEG measures in a steady state evoked potential task. We will also discuss issues of robustness under misspecification.

Monday, 10:40
Courville & Montmorency

A theory of between-trial variability in diffusion models Matt Jones, *University of Colorado, United States of America* ■ Diffusion models of speeded choice provide excellent accounts of accuracy, the distribution of correct response times (RTs), and their dependence on various experimental factors. However, they cannot account for error RTs without additional assumptions that the drift rate and starting point of the evidence process vary across trials. If this across-trial variability is governed by arbitrary probability distributions, the model becomes unfalsifiable (Jones & Dzhafarov, 2014). Here I offer a theory of across-trial variability based on sequential effects from incremental learning. This theory makes precise predictions about how model parameters vary from trial to trial, thus eliminating the problem of excess flexibility. I explore three types of sequential effects (from learning the response base rate, drift rate, and drift criterion), grounded in the classical interpretation of the diffusion model as a sequential likelihood ratio test. The resulting model can reproduce the benchmark crossover effect (fast errors under speed instructions, slow errors under accuracy instructions) that is held as the primary evidence for across-trial variability.

Regular Session 13

Chair: Jim Neufeld

Monday, 14:00
Port-Neuf & Ste-Foy

Decisional Control: A Normative Model of Cognition-Intensive Coping with Stress Richard W.J. Neufeld, *Western University, Canada*, Matthew J. Shanahan, *Western University, Canaa*, Nguyen Peter, *Western University, Canada* ■ Decisional Control (DC) is a method of coping with potential psychological stress by positioning oneself in a multifaceted stressor situation so as to minimize the probability of an untoward physical or social event. Translating the essentials of DC into rudimentary sentential logic ushers in quantification of its key properties. These properties include the sheer availability of DC in the environment, its potential for reducing stressor occurrence, and the cognitive load (predictive judgments) imposed by its exercise, the latter being demonstrably stressing in its own right. Instantiating the above developments with respect to structured environmental prototypes, provides a substantive context for applying specific combinatorics that precisely convey the threat-reducing benefits, and cognitive-load costs of DC. Presented are resulting implications for quantifying DC properties of the immediate environment; individual differences in tendencies toward the appropriation of available DC; adverse effects on its efficacy of uncertainty about choice consequences, in DC's operative environment; inherent linkages of this cognition-intensive form of coping with selected aspects of quantitative cognitive science; and informing the nature of nonlinear-dynamical systems accounts of stress and coping. Empirical support for the normative model takes the form of behavioural and psychophysiological experimental data.

Monday, 14:20
Port-Neuf & Ste-Foy

Axioms for useful risk-seeking: Rationally liking both sides of the bet. Peter Sunehag, *Australian National University, Australia*, Marcus Hutter, *Australian National University, Australia* ■ We discuss axioms for agents do-

ing sequential decision making in an unknown uncertain world. First, a system of axioms that implies that the agents maximize expected utility according to some a priori belief is presented. Then we present a weaker set by breaking a symmetry assumption saying that if one strictly likes one side of a bet one does not like the other. The new condition says that one likes at least one side. The new set is motivated by the fact that in most real situations, one cannot even approximately maximize expected utility for the full horizon that matters (e.g. one's life), and if one is maximizing expected utility over a shorter horizon one fails to explore promising possibilities that could reveal far more rewarding strategies. Though the work is prescriptive decision theory, risk-seeking/optimistic behaviour is prevalent and found in almost all mentally healthy humans. In computer science, optimism is often used to make reinforcement learning algorithms sufficiently and systematically explorative. We seek to illuminate mathematically exactly how this bias is useful or in other words adaptive and reasonably selected for in our evolutionary past. This talk will focus on axiomatic decision theoretic foundations while we have also studied performance guarantees for optimistic reinforcement learning agents.

Monday, 14:40
Port-Neuf & Ste-Foy

Subjective Hazard Rates Imply Non-Stationary Intertemporal Preferences
Christian C. Luhmann, *Stony Brook University, United States of America*, Michael T. Bixter, *Stony Brook University, United States of America* ■ Delay discounting refers to decision makers' tendency to treat immediately consumable goods as more valuable than those only available after some delay. Past work has found decision makers systematically exhibit more patience when consequences are far in the future but less patience about those same, identical rewards as time passes. Such non-stationary preferences are at odds with conventional economic models and have been deemed irrational (e.g., subject to arbitrage). One explanation for delay discounting itself appeals to the risk implicitly associated with delayed rewards, however, the relationship between implicit risk and non-stationary intertemporal preferences has received little empirical attention. We elicited subjective beliefs about the hazard rates present in a variety of real world situations. Specifically, participants were asked for the probability of a reward surviving the interval between now and time dt given that it has already survived for some interval t. Results indicate that these subjective risk judgments increased as t increased. This finding is consistent with a decreasing hazard rate; the longer the reward has already survived, the more likely it is expected to survive an additional dt. Furthermore, a decreasing hazard rate is exactly what would be expected given the standard pattern of non-stationarity typically observed in intertemporal choice. To explore this finding further, we used participants' subjective risk judgments to reconstruct the idiosyncratic discounting functions they implied. These reconstructed discount functions were strongly related to individual difference in the degree to which participants exhibit non-stationary intertemporal preferences in an independent choice task. These findings suggest a parsimonious explanation of a problematic and seemingly irrational pattern of behavior and, more generally, provide support for the hypothesis that im-

plicit risk is a critical mechanism underlying intertemporal preferences.

Regular Session 14

Chair: Denis Cousineau

Monday, 14:00
Courville & Montmorency

Detecting the undetectable or informing NHST of the presence of measurement error Denis Cousineau, *Universit'é d'Ottawa, Canada* ■ Null-hypothesis statistical testing (NHST) are built to detect effects that are embedded within sampling error. However, sampling error is not the only source of error altering data. Measurement errors related to the measuring instruments also contaminate the data. Current tests, being uninformed of this source of error, can detect infinitely small effects, as long as sample sizes are large enough. This should not happen as differences smaller than measurement errors are in reality undetectable. Here we show how measurement error can be propagated to the level of the test statistic. We also show the results for a few simple tests. Finally, we discuss implications with regards to error bars and statistical testing.

Monday, 14:20
Courville & Montmorency

Independent Validation remedies α inflation in Classifier Accuracy Testing Timo von Oertzen, *University of Virginia, United States of America*, Bommae Kim, *University of Virginia, United States of America* ■ To statistically test whether a classfier is better than guessing, the performance of the classifier is often tested against a Binomial Distribution. For independent samples, Cross-Validation (CV) and in particular Leave One Out (LOO) accuracy are better estimates of the classifier performance than the accuracy on a test set, and are frequently used for testing in practice. However, it has been argued that the multiple use of items creates dependencies between classifications that compromises the Binomial distribution. We formally show that in fact the CV accuracy of a classifier is not Binomially distributed under the null hypothesis of no group differences. We give a minimal independence condition that validation methods need to satisfy to guarantee Binomial distributions and suggest Independent Validation (IV), a new validation method that gives an optimal true estimator for the population accuracy under this condition providing optimal information about the classifier accuracy.

Monday, 14:40
Courville & Montmorency

Specification, diagnostics and interpretation of location-dispersion models for RT data. Seamus W Donnelly, *CUNY Graduate Center, United States of America*, Verkuilen Jay, *CUNY Graduate Center, United States of America* ■ While response latencies (RT) have been a key source of psychological data since the 19th century, they have often proven challenging to analyze. A particularly problematic characteristic of RT data is heterogeneity of variance. One solution to this problem has been to transform RT data, an approach that implicitly views the variance as a nuisance parameter. However, differences in variances between participants or experimental conditions may be theoretically significant, in which

case successful transformations may discard an important characteristic of the data. A promising approach, the location-dispersion (or location-scale) model fits regression structures to both the location and dispersion components of a distribution, allowing explicit modeling of means and variances simultaneously. The model has been used to estimate theoretically significant differences in variance in judged probabilities and confidence ratings (Smithson, Merkle & Verkuilen, 2011) and has recently been used on RT data (Schmiedek, Lövdén, & Lindenberger, 2009; Rast, & Zimprich, 2011). While promising, this model can be extremely challenging in practice. First, in many cases, complicated random effects structure may be difficult or impossible to fit because of non-regular or ill conditioned likelihoods. Second, as many researchers are accustomed to viewing heteroscedacticity as a nuisance rather than a study outcome, diagnostics and model interpretation may not be intuitive. We propose a set of graphical and simulation methods for addressing these challenges. First, we use a set of graphical methods for determining appropriate model specification, including the proper distributional family and appropriate random-effects structure. Second, we propose a set of simulation methods, drawing on the work of Longford (2001), for model diagnostics and interpretation. We illustrate our method using data from common RT tasks, such as task switching and the flanker interference task.

Abstracts For Posters

Poster abstracts in alphabetical order

(# 1)

Modeling Feature Processing in Object/Face Recognition Maxim Bushmakin, *Indiana University, Department of Psychological and Brain Sciences, United States of America* ■ The ability to identify and categorize faces and objects is essential for successful interactions with one's environment. There is considerable amount of evidence indicating that the visual system processes faces differently from other objects. A common explanation for these effects is that upright faces are processed by a holistic system, while everything else - including inverted faces – is processed through a featural system (Maurer, Grand, & Mondloch, 2002; McKone, 2009). However, there is a need for more mechanistic explanations of these effects. The current work proposes a model that integrates information across multiple features of the visual stimulus and multiple spatial frequencies using an ensemble of Linear Ballistic Accumulators (Brown & Heathcote, 2008; Eidels, Donkin, Brown & Heathcote, 2010). To test this model, subjects performed a face identification task using faces of three famous people. Modeling results suggest that inversion effects in accuracy and reaction times found with face stimuli can be explained by the difference between an integrative information accumulation with upright faces and a simple single feature accumulation with upside down faces.

(# 2)

Further examinations of the mathematical properties of behavior induced by concurrent schedules of reinforcement Pier-Olivier Caron, *Université du Québec À Montréal, Canada* ■ The generalized matching law is a mathematical model from the quantitative analysis of behavior describing response ratios of an organism as a function of their associated reinforcer ratios (Baum, 1974). It has been frequently found to explain over 80% of the variance in concurrent schedules of reinforcement (Davison & McCarthy, 1981). However, Caron (in press) showed by means of simulations that sampling an organism's responses and reinforcers was systematically bias by their interdependency. He showed that the matching law could account for 47% of the variance without implying any behavioral processes. The purpose of the current study is to further examine the influence of systematic bias induced by concurrent schedules of reinforcement. A Monte Carlo approach based on Caron's works was used to assess the effect of implementing a maximum number of possible responses and reinforcers in a single session on the parameters of the matching law.. This systematic bias has already been discussed in matching theory (Herrnstein, 1970; Rachlin et al., 1981), but its impact

has not been studied. Results show that adding this bias in the simulation increases the explained variance to 63%. Results are discussed in comparison to the genetic algorithm developed by McDowell (2004; 2013) which implies that the generalized matching law is an emergent property of the selection by consequences (Skinner, 1981) and for their contribution to evaluate matching theory in natural settings.

(# 3)

Median thinking style predicts the individual differences in processing capacity Ting-Yun Chang, *National Cheng Kung University, Taiwan, Republic of China*, Cheng-Ta Yang, *National Cheng Kung University, Taiwan, Republic of China* ■ The present study investigates how an individual's median thinking style, or Zhong-Yong in Chinese, is related to his/her cognitive processing capacity. In two experiments, participants completed a median thinking scale and performed a redundant-target detection task. Processing capacity was assessed by nonparametric (systems factorial technology, SFT) and parametric (linear ballistic accumulator model, LBA) approaches. Results showed a positive correlation between Zhong-Yong propensity score and processing capacity. High median thinkers had larger processing capacity in multiple-signal processing compared with low median thinkers, indicating that they processed information more efficiently in an integrated way. Median thinking style can predict individual differences in processing capacity. These findings provide a plausible account for the reasons why high median thinkers tend to adopt a global and flexible processing strategy when they deal with the external world.

(# 4)

Reward effects in a sequential trajectory learning paradigm Roy De Kleijn, *Leiden University, Leiden Institute for Brain and Cognition*, George Kachergis, *Leiden University, Leiden Institute for Brain and Cognition*, Bernhard Hommel, *Leiden University, Leiden Institute for Brain and Cognition* ■ The serial reaction time task (SRT) is used to study implicit and motor learning research which aim to explain complex skill acquisition (e.g., learning to type). In the SRT task, subjects tend to increase their speed of responses as they learn the order of the sequence. However, human action is not about reproducing a sequence of discrete responses, and is better characterized by its continuous nature. Therefore, we adapted the SRT task using a trajectory paradigm, where we also found the speedup visible in the original SRT task. In addition, we found evidence for sequence segmentation by comparing response times within subsequences to response times between subsequences. By providing a reward at either random, end-of-subsequence or start-of-sequence positions, we also found an effect of reward position on segmentation performance. In the current paper, we introduce a model that can account for both overall speedup, as well as these segmentation effects.

(# 5)

Examining Image Display Types using Systems Factorial Technology Elizabeth L Fox, *Wright State University, Dayton OH*, Joseph W. Houpt, *Wright State University, Dayton OH* ■ Several types of sensors are used to capture imagery to provide information to human

observers. Images from each sensor can be presented to an observer individually, or the images from multiple sensors can be algorithmically combined into a single image. The various algorithms for fusing images have been studied from an information theoretic viewpoint, but the advantages (or disadvantages) of fusion for human perceptual and cognitive processing have received relatively little attention. Systems Factorial Technology (SFT; Townsend & Nozawa, 1995) is general framework for assessing of how human observers process multiple sources of information. We applied SFT to measure how observers perform with images from different sensors separately (side-by-side). This performance was used as a baseline to compare performance with fused imagery. Because there are two separate images in the side-by-side presentation, there may be some statistical facilitation of the processing times, while fused presentations eliminate the need to attend to both sides. These two potential gains seem to trade off we found roughly equivalent workload capacity levels, limited for all participants, in both conditions. The survivor interaction contrast (SIC), another measure of SFT, indicated most individuals processed the side-by-side images sources of information simultaneously (in parallel) while responding with the first completed source. Despite the roughly equal capacity, the fused images result in slightly faster response times than the redundant side by side images at the group level, with all sensor types being equally fast with no significant interaction. While the fused imagery is processed slightly faster, performance with the side-by-side presentation is quite good because participants were able to process the images in parallel. Given that there is necessarily some loss of information in the fused images, it may be advantageous to use side-by-side images even in time critical applications.

(# 6)

There is Only One Domain in Stages of Development Sagun Giri, *Dare Institute*, William Joseph Harrigan, *Harvard University*, Michael Lamport Commons, *Harvard Medical School* ■ Gilligan (1992) claimed that Moral Judgment and Care formed different domains. Kegan (1982) asserted that there was just one domain. This study used the Model of Hierarchical Complexity (MHC) to find out whether task performances across subdomains form a single domain. The two subdomains were the logic/mathematics/physical sciences subdomain and the social/moral/caring/empathy/persepctive-taking/informed-consent subdomain. If there is just one domain that would support Piaget's theory of synchrony of development across subdomains. The Model of Hierarchical Complexity (MHC) is a neo Piagetian mathematical model that allows for the measurement of stage performance. MHC classifies tasks as to their Order of Hierarchical Complexity (OHC). This allows for the separation of task characteristics and the resulting performance on those tasks instead of confounding the two, as Piaget's work did. This model specifies more stages than Piaget's theory. Also, it can be applied to any series of tasks that may be sequenced hierarchically. A higher order task is: a) defined in terms of two or more tasks at the next lower Order of Hierarchical Complexity; b) the higher order task organizes the less complex actions; and c) the lower order tasks have to be carried out non-arbitrarily, not just as an arbitrary chain of actions. Once these

conditions have been met, we say that the higher-order task coordinates the tasks of the next lower order.The instruments belonged to the following subsubdomains: mathematical (Algebra & Infinity), logical (Laundry version of the Pendulum problem), or physical science (balance beam) caregiver-person relationship (Counseling, Child Caregiving, Empathy, Helping), and depression (Romantic Breakup). Four analyses were carried out. First, Rasch analysis yielded person scores akin to person stage scores. Principal components analysis was performed on these person scores. Irrespective of domains, each instrument loaded on the first factor with all the factor scores over 0.92, explaining 92% of the variance. Although the idea of domain specific development is not new (Kegan, 1982; 1994), empirical identification that there is only a single domain using the Model of Hierarchical Complexity helps to explain why people who exhibit behavior of a high order of hierarchical complexity in one subdomain relatively easily learn to do behavior in another subdomain.

(# 7)

Using adaptive psychophysical methods to individualize studies involving Systems Factorial Technology
Joseph James Glavan, *Wright State University, United States of America*, Joseph W. Houpt, *Wright State University, United States of America*
■ Systems Factorial Technology (SFT; Townsend & Nozawa, 1995) provides procedures for determining the architecture (e.g., parallel, serial, coactive) and stopping rule of a cognitive process that incorporates multiple sources of information. In order to reliably measure the function used to infer architecture, the Survivor Interaction Contrast (SIC), the researcher must selectively speed up and slow down the processing of each source of information by manipulating the saliency of the sources. While the same saliency manipulations may be suitable to measure the SIC for all subjects in some experimental designs, individual differences are often great enough to necessitate the estimation of individualized signal intensities corresponding to low saliency and high saliency for each signal for each subject before they participate in the experiment proper. Traditional psychophysical methods, which target response accuracy, have been used under the assumption that the lower saliency, which produces lower accuracy, also produces larger response times. The challenge with using accuracy based psychophysical methods is that a low enough accuracy threshold must be targeted so as to elicit the necessary slow down in processing while still maintaining an accuracy rate high enough to collect enough correct response trials in the experiment proper to ensure appropriate statistical power when measuring the SIC. Because the time a researcher has to collect data from a subject is limited, and the SIC itself requires many trials to be measured, an adaptive psychophysical method is essential to minimizing the time spent parameterizing the experiment to the individual subject. The Psi method (Kontsevich & Tyler, 1999) has been identified as such a procedure suitable for pairing with SFT because it has the ability to efficiently estimate the location and slope of a psychometric function, both of which may vary across individuals. An implementation of the Psi method in Python developed specifically for inclusion in the open source package PsychoPy (Peirce, 2007) is described. By using the Psi

method implemented in PsychoPy together with the 'sft' package (Houpt & Blaha, 2013) in R, researchers have the ability to easily create and analyze experiments that investigate the workload capacity and architecture of cognitive processes.

(# 8)

Validating Recognition Memory Models for a Task with Ternary Response Options Quentin Frederik Gronau, *Albert-Ludwigs-Universität Freiburg, Germany*, Axel Rosenbruch, *Albert-Ludwigs-Universität Freiburg, Germany*, Paul Bacher, *Albert-Ludwigs-Universität Freiburg, Germany*, Henrik Singmann, *Albert-Ludwigs-Universität Freiburg, Germany*, David Kellen, *Albert-Ludwigs-Universität Freiburg, Germany* ■ There are two prominent classes of recognition memory models for disentangling memory and response processes that rely on different assumptions concerning the underlying memory processes. Models based on Signal Detection Theory (SDT; Green & Swets, 1966) assume a continuous memory process, whereas others, most prominently the Two-High-Threshold model (2HTM, Snodgrass & Corwin, 1988), assume discrete memory states. However, unless questionable parameter restrictions are introduced, for example restricting the signal variance to be equal to the noise variance in the SDT framework (see Kellen, Klauer, & Bröder, 2013), the model parameters are not fully identified for a single set of hits and false alarms. One way to obtain fully identified model parameters is to introduce a third response option ("unsure" or "skip"; Singmann, Kellen, & Klauer, 2013). We validated fully identified extensions of the 2HTM and unequal variance SDT for a recognition memory task in which we introduced an "unsure" response option (Singmann, Kellen, & Klauer, 2013). Specifically, we established a double dissociation of memory strength and response tendencies. To manipulate memory strength some items were shown once whereas other items were shown thrice in the study phase. To manipulate response tendencies we implemented different payoffs associated with correct, unsure and erroneous responses between test blocks (between subjects we used two different such manipulations). As expected, memory manipulation solely affected memory parameters, whereas different payoff schemes solely affected guessing parameters. This study also yields further evidence that recognition memory performance is more adequately measured by models assuming discrete latent memory states instead of a continuous memory distribution, as the 2HTM provides a better account to the data in terms of AIC and BIC which is in line with other recent results (Kellen, Klauer, & Bröder, 2013; Province & Rouder, 2013).

(# 9)

Mathematical modeling of the structure of motivation to achieve of managers Vera Gryazeva-Dobshinskaya, *South Ural State University, Russian Federation*, Yulia Dmitrieva, *South Ural State University, Russian Federation* ■ A topical issue in organizational consulting is the selection of managers, who may be efficiently taught new professional competences during the introduction of innovations. The basis for the successful realization of activity and efficient teaching during the introduction of innovation is the presence of innovative activity of managers as leaders of innovations. The resources required for managers' innovative activity, required to achieve the aims

during introduction of innovations include the ability to make predictions, take risks, act in a situation of uncertainty, and, most important, to be motivated to achieve results. The motivation to achieve is a crucial resource of a manager's innovative activity, containing two motivational tendencies - the "hope for success" and "failure avoidance". To study the structure of enterprise managers' motivation to achieve, the Thematic Apperception Test by H. Heckhausen was used. This method is included in the program of the psychological innovative audit by V.G. Gryazeva-Dobshinkaya, to analyze the resources of managers' innovative activity. The innovative audit discovers the balance of two trends in managers' activity: research activity, aimed at a change of existing parameters of an organization's functioning, and stabilization activity, aimed at maintaining the parameters of an organization's functioning. 515 managers from industrial enterprises took part in the research. The research shows that the discovery of motivation to achieve, as a resource of managers' innovative activity, may be based on psychological diagnosis methods and methods of mathematical modeling of the correlation between the activity trends aimed at a change or the maintenance of an organization's functional parameters. In order to model managers' innovative activity resources, the model of the biologic self-developing system functioning by V. Volterra, was used. This combined equation facilitates modeling of the integration of two trends of innovative activity, based on data received as a result of psychological diagnosis of the structure of motivation to achieve. As a result of the mathematical modeling of the motivation to achieve, a model of the training impact optimum point ("balance point") was developed. Based on methods of mathematical modeling of managers' innovative activity resources, we may develop a program of differentiated training for different groups of managers to optimize the discovered structure of the motivation to achieve.

(# 10)

An investigation of time pressure on framing effects in risky choice
Lisa Guo, *University of California, Irvine, United States of America*, Jennifer S. Trueblood, *University of California, Irvine, United States of America*, Adele Diederich, *Jacobs University Bremen, Bremen, Germany*
■ Recent neurological evidence suggests that framing effects in risky choice are the result of two different systems of reasoning - one that is fast and emotional and another that is low and rational. Framing effects occur when participants exhibit risk adverse behavior in choices framed as gains and risk seeking behavior in choices framed as losses. In an fMRI study, De Martino et al. (2006) found greater activation of the amygdala when participants were risk averse in gains and risk seeking in losses, which supports the idea that framing effects are driven by an emotion system. Based on this hypothesis, we developed a new experiment to examine the effect of time pressure on framing effects. If framing effects are the result of a fast, emotional system, then we expect more pronounced framing effects under time pressure. In our experiments, participants made choices between a gamble and a sure option, which were either framed as gains or losses We also included a speed manipulation in which time pressure is applied to participants to make decisions quickly and an accuracy manipulation in which participants are encouraged to take as long as necessary to maximize the

amount of money earned. We aim to find a best-fitting model across a variety of cognitive models, including exploring the interaction of the two thinking modes through sequential as well as parallel operation.

(# 11)

The Transition to Ultramodern Society: Rethinking Politics, Stage, And Source Of Information William Joseph Harrigan, *Harvard University*, Michael Lamport Commons, *Harvard Medical School*, Sagun Giri, *Dare Institute* ■ The study discusses a major theme in the development of ultra-modern science. The theme is understanding the three main sources of knowledge: Analytic, empirical, and experiential. These three main sources of knowledge each have their purpose. Logic, mathematics and set theory are subsets of the analytic domain of knowledge. Science and history are subsets of the empirical domain of knowledge. There are two trends in pre-modern science that would be rectified by ultramodern science. First, is the self-deception achieved by relying on experiential knowledge over empirical knowledge. Second, is the reliance on composite variables in research. Composite variables such as age or education are variables that cover a wide range of possible causes, and have low effect sizes. Modern scientists, although empirical, use composite variables to build accounts. These composite variables do not describe actual empirical events or the relationship among those events as described by contingencies. Behavioral science, social science and medical science rarely use general models. The general mathematical models of development are required. These replace the piecemeal, ununified accounts from testing hypotheses one at a time. This study also points out that the culture as it is today, is in transition to an ultramodern society where general models in science, including behavioral science, social science and medical science use empirically tested analytic models. Five characteristics of ultramodern models are described below. 1. The best general models consist of sets of mathematical axioms, mathematical definitions, and theorems that describe the properties of how events in the world interact. 2. The tests of those models should have predictions with $r = s$ of about .9, generally ranging up to .98. 3. General models hold across entire fields. They do not have much content and do not vary in their fundamental character with culture. 4. The models have actual direct or indirect measures of variables. They have good scale properties that do not include composite variables. However, relationships among them the variables may generate useful composite variables. 5. The variables cannot be decomposed into simpler variables. Sociology and criminology violate this.

(# 12)

Total Free Recall: Trial-level analysis of memory models within a Bayesian framework Adam E Hasinski, *The Ohio State University, United States of America*, Brandon M Turner, *The Ohio State University, United States of America*, Per B Sederberg, *The Ohio State University, United States of America* ■ Traditional approaches to the study of memory have relied on summary statistics to assess model fit. This approach is flawed because, in practice, most summary statistics are not sufficient to describe a set of data. For example, whereas a serial position curve cap-

tures what an individual recalls, it does not describe the order in which those items were recalled. To combat this issue researchers tend to combine multiple summary statistics in hopes of capturing the important features of the data, though this is rarely guaranteed. Additionally, the focus on global patterns in aggregate data potentially forsakes important subject- and trial-level information. To solve these problems, we propose a method of fitting memory models to individual responses, including both individual responses and interresponse times (IRTs). In doing so, we circumvent the issue of assessing the sufficiency of statistics because the data are, by definition, sufficient to describe themselves. Our approach uses model simulation to construct an approximation to the true (unknown) likelihood function (Turner & Sederberg, 2013). We then use the approximation at the individual trial level to perform a proper Bayesian analysis. We demonstrate the effectiveness of this approach by fitting a model of free recall (TCM-A; Sederberg et al., 2008) to trial level data from immediate, delayed, and continual-distractor free recall sessions from individual subjects. In doing so, the model is able to generate responses that not only align with summaries of the data, but also with item-level responses from individuals. More importantly, we argue that now recall models can be couched within a Bayesian framework, providing a powerful method for model comparison, selection, and development.

(# 13)

The relationship between memory for associations and memory for constituent order Kenichi Kato, *University of Alberta, Canada*, Jeremy B. Caplan, *University of Alberta, Canada* ■ Two popular classes of association-memory models take on opposite positions about the order of items within associations. Matrix models perfectly distinguish A-B from B-A whereas convolution models cannot. Two studies measured memory for constituent-order by asking participants to distinguish intact (A-B) from reversed (B-A) probes (Green & Tussing, 2001; Kounios et al., 2003), and found that participants did better than chance, but these procedures did not include tests of memory for the association itself, such as recombined probes (A-D). Rehani and Caplan (2011) asked participants to use the direction of associations to resolve associative interference, and participants were moderately successful, suggesting they could recover some order information. Here we examined the relationship between association-memory and constituent-order by testing both in the same experiment, and manipulating whether participants needed to attend to constituent-order during study. Sixty-seven participants were divided into an order-relevant group (Order) and an order-irrelevant group (No-Order). Participants studied sets of noun-pairs followed by cued-recall. The Order group then performed order-recognition judgments (intact, A-B, versus reversed, B-A), and the No-Order group performed associative-recognition judgments (intact, AB, versus recombined, A-D). After six such blocks, half the participants in each group had a final order-recognition test of all the pairs, and the other half had a final associative-recognition test. The Order group performed better (but not exceedingly well) in final order-recognition than the No-Order group, showing that it is possible to willingly learn more order than participants spontaneously do. However, the groups performed equivalently in cued re-

call, suggesting that attending to order carried no cost association memory. The correlation between cued recall and d' in the final order-recognition test showed a trend toward being lower for the Order group than the No-Order group. This suggests that the small amount of constituent-order memory the No-Order group had was an intrinsic property of their associations. In contrast, the additional capacity for order-memory judgments that the Order group had may have resulted from an additional order-coding process that was unrelated to the way they stored associations. Existing models of association-memory need to be modified to explain these findings.

(# 14)

Recognition Memory Models and Confidence-Rating ROCs: A Comparison by Normalized Maximum Likelihood David Kellen, *University of Freiburg, Germany*, Karl Christoph Klauer, *University of Freiburg, Germany* ■ The ability to recognize previously encountered information is one of the most popular topics in memory research, with substantial efforts being devoted to the development of models establishing connections between cognitive processes and observed responses. Several recognition-memory models postulating continuous processes, discrete states, or a mixture of both have been proposed in the literature. Ongoing model-comparison efforts have almost invariably relied on Receiver Operating Characteristics (ROC) data (for a review, see Yonelinas & Parks, 2007). When comparing models, the goal is to find the model that strikes the best tradeoff between goodness of fit and flexibility, but a major problem lies in having a good index for model flexibility: Common indices (e.g., AIC and BIC) usually ignore the flexibility associated to the models' functional forms. An alternative model-selection index, Normalized Maximum Likelihood (NML), provides a more detailed characterization of model flexibility. Previous NML work on binary-response ROC data (Kellen, Klauer, & Bröder, 2013; Klauer & Kellen, 2011) has shown that popular recognition-memory models differ in their flexibility to fit data in general, differences that affect model comparisons in a non-trivial way. The present work evaluates model flexibility in the context of confidence-rating ROC data. This type of data is particularly interesting for several reasons, one of them being that recognition-memory models postulating discrete states have to specify a series of nuisance parameters describing how those states are mapped onto the confidence-rating scale. The present work reports NML penalties for confidence-rating ROC data and shows that model flexibility according to the NML metric diverges from AIC and BIC penalties. Furthermore, a reanalysis of previously-published data using a large set of candidate models shows that flexibility differences play an important role in model-comparison results.

(# 15)

A Bayesian analysis of speed-accuracy trade-off data Asli Kiliç, *Koc University, Turkey*, Ilke Öztekin, *Koc University, Turkey* ■ The speed-accuracy trade-off (SAT), caused by individuals' tendency to trade response time for accuracy and vice versa, is a common problem in two-choice decision tasks. One way to account for this tendency is to employ a response deadline procedure. By providing a full time-course function describing how cognitive processing unfolds over time, the response deadline

procedure can allow unbiased estimates of accuracy and speed independent from each other. In this investigation, we applied the Bayesian theory to estimate the accuracy and speed parameters of SAT functions obtained from the response deadline procedure. The proposed model is derived from a Bayesian signal detection framework and defines accuracy as an exponential growth function of total processing time. We applied the proposed model to hypothetical data sets, and evaluated the obtained parameter estimates for validity. Our findings suggest that the proposed Bayesian framework can provide an effective approach to model SAT curves.

(# 16)

A Bayesian Race Model to Decompose Recognition Memory Performance Sungmin Kim, *The Ohio State University, United States of America*, Kevin Potter, *The Ohio State University, United States of America*, Peter Craigmile, *The Ohio State University, United States of America*, Mario Peruggia, *The Ohio State University, United States of America*, Trisha Van Zandt, *The Ohio State University, United States of America* ■ Many psychological models make use of the idea of a trace, which, generally speaking, represents a change in a person's cognitive state that arises as a result of processing a given stimulus. These models assume that a trace is always laid down when a stimulus is processed. In addition, some of these models explain how RTs and response accuracies arise from a process in which the different traces race against each other. In this talk we present a Bayesian hierarchical model of RT and accuracy in a difficult recognition memory experiment. The model includes a stochastic component that probabilistically determines whether a trace is laid down. The RTs and accuracies are modeled using a minimum gamma race model, with extra model components that allow for the effects of stimulus, sequential dependencies, and trend. Subject-specific effects, as well as ancillary effects due to processes such as perceptual encoding and guessing, are also captured in the hierarchy. Marginal likelihood evaluations show better predictive performance of our model compared to an approximate Weibull model.

(# 17)

Spatially-global interpolation of closed curves Tae Kyu Kwon, *Purdue University, United States of America*, Kunal Agrawal, *Purdue University, United States of America*, Yunfeng Li, *Purdue University, United States of America*, Zygmunt Pizlo, *Purdue University, United States of America* ■ Most previous methods focused on spatially local interpolation using rules such as proximity, co-linearity, co-circularity and relatability. We propose a spatially global model based on finding the shortest path in the log-polar representation of the image which is a good approximation to the topographical map of the retina in the area V1. The shortest path in a log-polar representation corresponds to a smooth, convex and closed curve in the retinal image. As such, our method implements three fundamental rules of Gestalt perceptual organization: closure, convexity and good continuation. Producing a shortest path is computationally simple. At the same time the shortest path interpolates missing parts of a contour and ignores pieces of contours that are likely to represent noise. Three subjects were shown fragmented convex polygons (targets) embedded in uniformly distributed noise

line segments. A random polygon was generated as a convex hull of 10 randomly generated points. The polygon (target) was fragmented into linear pieces with equal length. Furthermore, the orientation of each contour fragment of the target was randomly perturbed by ± 10 to 50 deg. The subjects were asked to draw a contour perceived as representing the target. They drew the contour on the tablet computer with a stylus pen. They were encouraged to draw it quickly so that the contour they produced was likely to represent what they saw right after the stimulus was shown. The model was applied to the same stimuli. Both the subjects and the model started the reconstruction at a line segment that was thicker than other line segments. When the perturbation of orientation was small, the subjects reconstructed the targets very reliably and the model produced closed contours that matched the ground truth quite well. When the perturbation increased, performance of the subjects and of the model deteriorated. The correlations between the subjects and the model were high implying that the model integrated the fragmented contours very much like the human subjects did. We conclude that the shortest path model in the log-polar coordinates provides a possible explanation of how humans integrate the fragmented contour in a spatially global way. This model incorporates several existing principles in a simple mathematical way.

(# 18)

Exploring Big Data Analytics: Evaluating Hadoop-Based Software by Seeking Predictors of Psychological Well-Being in a Large Canadian Sample Canaan Legault, *King's University College at the University of Western Ontario, Canada*, Imants Barušs, *King's University College at the University of Western Ontario, Canada* ■ The current study examined the emerging field of big data analytics to assess the utility of this technology for typical psychological research. A study looking for predictors of psychological well-being within Statistics Canada data sets was designed as a means of testing the capabilities of standard statistical software (SPSS and R) for a large data set, by psychological standards, (N = 681,578) in addition to acting as a means of comparison for big data programs. Results of multiple linear regression using standard statistical software included finding health, stress, relationships, income, diet, exercise, education, and alcohol abuse to be predictors of psychological well-being. SPSS was found to be able to analyze large data sets (taking 3,651 seconds to produce output for a 54 gigabyte file), however, since big data is considered to be within the terabyte to petabyte range, it may be unreasonable to use this software for big data analysis due to the amount of time required to produce output. Thus, attempts were made to replicate the process using big data analytics software. It was decided that a selection of leading programs based on the industry standard Apache Hadoop would be used for this comparison including Hortonworks Sandbox 1.3 (running on a Linux based CentOS virtual machine), Cloudera Distribution Including Apache Hadoop 4.5.0 (running on a Linux based CentOS virtual machine), IBM InfoSphere BigInsights QuickStart 2.1 (running on a Linux based Red Hat virtual machine), and Microsoft's Windows Azure (an online cloud service including HDInsight, which uses the Hadoop Distributed File System). However, all of these programs in their present format were found

to be unsuitable for this type of research. Possible deterrents that could explain why big data research is not being embraced by psychologists include issues related to cost and accessibility, a lack of integration of statistical capability with the big data software, lack of necessary programming skills on the part of users, and hardware requirements. Directions for future research and possible solutions are discussed with regard to these deterrents.

(# 19)

Equations for Stage of Functioning in Development and Education Patrice Marie Miller, *Salem State University, United States of America*, Michael Lamport Commons, *Harvard Medical School* ■ Predicting how likely it is that an individual will change stage is not well understood. Many models of change focus on only one kind of variable. For example, a model may emphasize the content and structure of the curriculum. Another model may emphasize motivational or support factors. Applying the Model of Hierarchical Complexity to this issue, we argue that bringing about change of this kind is in effect a paradigmatic stage task. Change in developmental stage and increase in knowledge, symbolized here as ΔB = distance between the required order of complexity of the higher order tasks and the order at which the person is successfully performing tasks; and the stimulus context × time on task × reinforcement for advancing. $\Delta B = t$ on task actively engaged in × pl getting answer right when placed in sequence correctly; $t = f(SR+$contingency for reinforcement for correct answers); $pl = f($being placed in the right place in the developmental sequence); Time engaging actively on a task is sensitive to contingent reinforcement of corrects. Rasch Analysis is used and Order of hierarchical complexity of items yields Person stage scores. Below the task required order, people have great difficulty responding correctly.

(# 20)

A Bayesian Approach to the Meanings of Color Descriptions Brian McMahan, *Rutgers University, United States of America*, Matthew Stone, *Rutgers University, United States of America* ■ Mapping color descriptions to the physical world is challenging for two reasons: (1) properties of the physical world are difficult to model and (2) language use is the result of pragmatic processes such as context sensitivity, task relevance, and speaker goals. We propose a model of color vocabulary that addresses the second challenge. We used Randall Monroe's crowdsourced corpus of human color judgments to model grounded representations of color labels. Â Participants were presented with a uniformly sampled color patch and allowed to freely label it. After controlling for factors such as nonsense and spam labels, the corpus consists of 100,000 participants, 829 color labels, and 2.17 million color value and label pairs. Â In keeping with semantic accounts of color vagueness (Williamson, 1996; Barker, 2002), we treat color judgments as using underspecified representations. Underspecification means leaving open the possible boundaries that can be used to delineate examples. For example, the region between green and blue can be labeled "blue" in a context. Once labeled, the possible boundaries for "blue" becomes constrained to those which make the labeling true. This can be used to uniquely distinguish between two similar objects. We assume a cognitive model of

the subject based upon Bayesian rational analysis (Anderson, 1991). In the model, subjects have underspecified representations and make semantic and pragmatic decisions to use them. The result of the methodology is the Lexicon of Uncertain Color Standards (LUX). We statistically evaluate LUX against two alternative approaches, showing improvement over a baseline Gaussian model and closely approximating an optimal performance model, despite having far fewer parameters. In conclusion, LUX captures people's color labeling behavior and further, offers a way to ground representations of linguistic meaning in the perceptual domain that respects context and speaker choice.

(# 21)

A Bayesian Sequential Sampling Model of Choice Reaction Time Incorporating Stimulus Onset/Duration Uncertainty JORDAN MEYER, *University of Michigan, United States of America*, JUN ZHANG, *University of Michigan, United States of America* ■ We propose a Bayesian sequential sampling model of choice reaction time (RT) that incorporates uncertainties about stimulus identity, onset, and duration. The model is the now-standard random-walk/drift-diffusion model, with a threshold-based response mechanism. The "substance" of the drift, however, is the posterior probability (belief) that a participant updates on a moment-to-moment basis during a trial. The update is done by combining the likelihood function on the evidence (modeling trial-dependent perception) with prior probability about stimulus identity, onset time, and duration (modeling trial-independent task knowledge). Response thresholds, which equal the probability of correct response in choosing each alternative conditioned on prior knowledge and accumulated evidence, modulate speed-accuracy tradeoff. While sequential Bayesian updating without temporal uncertainty (regarding stimulus onset/offset) is well-understood, we overcome the hurdle of incorporating the temporal prior into the dynamics of belief updating to derive an analytic expression for Bayesian belief. This framework allows for the natural modeling of a broader class of experimental paradigms than many other previous sequential sampling models. In general, the advantage of the Bayesian formulation is to allow full control of where and how many free parameters appear: in likelihood functions, priors, or response thresholds. Comparison of computer simulation of our model with human performance data (Smith, 1995) will be reported.

(# 22)

Quantum inference models of causal reasoning PERCY K MISTRY, *University of California Irvine, United States of America*, JENNIFER S. TRUEBLOOD, *University of California Irvine, United States of America*, EMMANUEL M POTHOS, *City University London, United Kingdom* ■ A hierarchal structure of causal reasoning between events can be represented using causal graphical models (CGMs), fulfilling the general causal Markov (CM) condition that stipulates patterns of independence and dependence among causally related variables. However, previous studies have found that in a variety of experimental conditions, subjects demonstrate large individual differences, with a substantial subset exhibiting the tendency to violate CM (Rehder, in press). Other violations of normative theories have also been recorded, such as

the failure to exhibit discounting in which the presence of one cause as an explanation of an effect makes the presence of another less likely. Various descriptive models have previously been proposed to account for these and other related effects, for instance, specifically modeling conjunctive or associative causal reasoning processes. However, most of these models account for a subset of conditions and require either multiple different models, or a complex model that averages across such distinct models to account for all the normative violations. We postulate quantum inference models to represent the causal reasoning structure that people use to make causal inferences, based on the axiomatic principles of quantum probability theory. These quantum models can account for individual differences, conjunctive and associative reasoning, and other violations of the normative models and CM condition. The quantum models capture these violations and differences by assuming different sequential paths to evaluating the causal reasoning structures. Overall, the quantum models provide a parsimonious description of the empirically observed data collected under various experimental conditions. The models also have easily interpretable psychological implications for the different thought processes that lead to individual differences and violations of CM. They provide good fits to the data and offer a coherent account for the observed effects with a small number of free parameters, thus proving to be a viable new candidate for modeling causal reasoning in adults.

(# 23)

Quantitative analysis of the relation between schoolchildren's response allocations and their teacher's social attention by means of feedback functions Caroline Montigny, *UQAM, Canada*, Pier-Olivier Caron, *UQAM, Canada*, Jacques Forget, *UQAM, Canada*, Philippe Valois, *UQAM, Canada*, Ariane Leroux-Boudreault, *UQAM, Canada* ■ Within the experimental analysis of behavior, feedback functions conceptualizes the interaction between an organism's behaviors and their obtained reinforcers or, in other words, a schedule of reinforcement (Baum & Nevin, 1980). Forget (1987) suggested that the schedules relating schoolchildren's response allocations and their teacher's social reinforcers could be investigated by means of feedback function. This relation can be depicted by proportional, interval or concurrent schedules of reinforcement which is more informative than a mere functional analysis. Even though some studies have evaluated feedback functions in natural settings, none has evaluated their relevance to direct intervention. The purpose of the current study is to assess the efficacy of feedback functions to identify the schedules of reinforcement in effect and their relevance to direct interventions. An experimenter observed four typical children in their classroom. Their behaviors and the social reinforcers were recorded according to Forget and Otis' scale (1984). The session length was ten minutes and each child was observed three hours during six weeks. A baseline was recorded. Each child's appropriate and inappropriate behaviors were analyzed by means of feedback function to identify whether their relations with social reinforcer corresponded to proportion (proposed by Rachlin, 1978), interval (Baum, 1973) or concurrent schedules of reinforcement (Baum, 1974). Interventions were then used to increase the attention to the

task of children. The intervention mainly consisted of feedbacks to the teachers about their own behaviors and how, according to baseline results, they should modify their interactions with the target child. Overall, all feedback functions described the data relatively well, but depended on the response-reinforcer relation and the child. Results show that feedback functions could suggest efficient intervention to raise the frequency of appropriate behavior. Differences between functions and their usefulness as well as considerations about the interventions are discussed. Still, the exploratory nature of the study, the idiosyncratic teacher-student relationships and the small sample size limit the generality of the current study. In conclusion, results suggest that feedback functions in natural settings should be more extensively investigated. They appear both adequate to identify the schedules of reinforcement in effect and to direct interventions.

(# 24)

A Hierarchical Bayesian Approach to Assessing Between-Experiment Generalizability of Models of Risky Decision Making Jay Myung, *Ohio State University, United States of America*, Yun Tang, *Ohio State University, United States of America*, Mark A. Pitt, *Ohio State University, United States of America* ■ The present study introduces a hierarchical Bayesian approach, dubbed Hierarchical Generalization Modeling (HGM), to assessing a model's generalizability between experimental tasks. The basic idea of HGM is to use a hierarchical modeling structure to evaluate the extent to which a model explains data observed in different experimental tasks and conditions that share some common underlying processes. The HGM approach represents an extension of the current methods of model selection, such as the Akaike Information Criterion and the Bayesian Information Criterion, that assess the generalizability of a model within a given experimental task. We demonstrate the soundness and feasibility of HGM for selecting among models of risky decision making with human data from decision-from-description and decision-from-experience experiments, as well as through simulations with artificial data. The results show that HGM can facilitate a comprehensive examination of experimental data across different experimental settings from a more integrated modeling perspective.

(# 25)

Color Preferences and Sampling Behavior in Recall for Color Kimele Persaud, *Rutgers University, United States of America*, Pernille Hemmer, *Rutgers University, United States of America* ■ Previous research suggests that prior categorical knowledge exerts strong influences on episodic memory. Although the interaction between this knowledge and memory has been previously examined, it remains unclear how individuals sample from their prior category knowledge. For color, a salient property of the environment, for which people have strong expectations, it has been shown that best examples of color within a given category are the source of naming preferences for universal color labels (Regier, Kay, Cook, 2005). This suggests that individuals sample only from a subset of the prior rather than broadly from the prior space. However, such sampling behaviors may be task dependent. Here we present a simple rational model of

the influence of categorical knowledge and expectations for color on episodic memory. The model assumes that noisy data in the mind is optimally combined with category knowledge of the environment to reconstruct events in memory. We further extend the model to assume that subjects do not sample from the broader hue space of each color category, but rather sample from a scaled distribution center on the prototypical or best color. This allows us to estimate parameters that describe how close to the prototypical color subjects generate their samples. We conduct a series of experiments in which we first probe individuals' bi-directional knowledge of color via a color naming task and a novel color generation task. Here we present the results of the bi-directional category knowledge task, and a memory task. We evaluate the model against this data.

(# 26)

Finding Subgroups in a Homogeneous Sample using Hierarchical Cluster Analysis and Three Linkage Measures Kylee Tamera Ramdeen, *Université de Savoie, Laboratoire de Psychologie et Neurocognition (CNRS UMR-5105), Chambéry, France, University of Ottawa, Canada*, Odilia Yim, *University of Ottawa, Canada* ■ Hierarchical cluster analysis is a useful data reduction technique that uncovers the group structure underlying multivariate datasets, and yet it is rarely employed in psychology research. The current study sought to investigate the various parameters of agglomerative hierarchical clustering and their impact on the obtained clustering solutions. In a sample of participants matched on various tests, between 3 to 5 clusters of subgroups were uncovered depending on whether single linkage, complete linkage, or average linkage between-groups was used, respectively. Upon review, the average linkage measure produced the most accurate and meaningful group structure. This study demonstrated the utility of cluster analysis in psychology research and the importance of selecting appropriate linkage measure for analysis.

(# 27)

A Bayesian Model of Belief-Updating Talia Robbins, *Rutgers University, United States of America*, Pernille Hemmer, *Rutgers University, United States of America* ■ While our beliefs play a fundamental role in our daily decisions, human belief updating is not yet fully understood. An important question in belief updating concerns how people recall the past and make predictions about the future based upon their current state of belief. We develop our theoretical framework specifically as it relates to medication adherence, using a simple rational model to capture the relationship between prior knowledge and evidence from the environment. Bayes rule predicts a tradeoff between prior beliefs and observed evidence: when our prior belief is strong, the posterior will closely reflect the prior; and when evidence is strong, the posterior will reflect the evidence. While the simple rational model would suggest that prediction for future events would be centered around the mean of the current belief, the experimental results indicate that this is not the case. Rather, only short-term predictions seem to hold this pattern, while long-term predictions appear to be a mixture of the belief about the local environment and a belief about the overall stimulus environment. We performed analyses on both memory and

prediction and propose a mixture model to explain this data. The mixture model assumes participants use a weighted linear combination of two belief distributions in order to recall from memory and make predictions about the future. One belief state is based on the overall state of the environment learned across all time steps (e.g. health over your lifetime), while the other belief state is based on the local state of the environment and only considers evidence from a small temporal window (e.g. a recent illness). Results are discussed in terms of patient beliefs and medication adherence.

(# 28)

Opportunity for verbalization does not improve visual change detection performance: A state-trace analysis Florian Sense, *University of Groningen, The Netherlands*, Candice C. Morey, *University of Groningen, The Netherlands*, Richard D. Morey, *University of Groningen, The Netherlands*, Melissa Prince, *University of Newcastle, Australia*, Andrew Heathcote, *University of Newcastle, Australia* ■ Decades of memory research have shown that stimuli can be encoded in a different modality than they were presented in. There seems to be a tendency to verbalize visual stimuli whenever possible and this has been used to argue that there are multiple components in short-term memory (STM). When studying visual STM, it has become common practice to employ articulatory suppression (AS) to exclude the possibility that participants articulated the visual stimuli and thereby boosted their memory performance. In visual change detection paradigms, though, there is some indication that AS does not affect performance markedly. Whether AS is needed in such tasks is an on-going debate. Here, we present new data and results from a state-trace analysis (STA) that suggests that AS is not needed. Small effects of an influence of articulation are usually based on significant interaction terms from an ANOVA, which is methodologically problematic. STA avoids such problems and provides a straightforward way to assess the effect of AS and the dimensionality of STM.

(# 29)

Modelling Causal Reasoning under Ambiguity Yiyun Shou, *The Australian National University, Australia*, Michael Smithson, *The Australian National University, Australia* ■ The current normative models of causal reasoning focus on reasoning with unambiguous observations, and assume that the observed causal evidence and probability information are complete and precise. Little attention has been paid to situations where the observed causal evidence and conditional probabilities are ambiguous. We propose a Bayesian hierarchical model to explore the possible cognitive mechanisms of causal reasoning from ambiguous evidence. We apply the cognitive toolbox approach proposed by Scheibehenne, Rieskamp and Wagenmaker (2013) to account for the inter-individual differences in the preferences of strategies for processing ambiguous causal information. We also attempt to account for the individual differences in knowledge of the functional forms of the causal structure. Functional forms indicate how different causes combine to influence the effect, determine how the causal links can be parameterized (Griffiths & Tenenbaum, 2006). We use both a parameter recovery simulation study and an analysis of experimental

data to demonstrate how this model framework may be used to explain people's causal judgments when presented with ambiguous causal evidence in different situations.

(# 30)

Assessing chance performance of the Category-Adjustment Model
Tyler Thrash, *ETH Zurich, Switzerland* ■ Huttenlocher, Hedges, and Duncan's (1991) Category-Adjustment Model (CAM) characterizes biases in spatial responses as resulting from a relative weighting of memory for a specific instance and memory for the superordinate category. For example, Huttenlocher and colleagues found that reproductions of a dot's location within a circle may be biased towards the center of one of the circle's quadrants (i.e., as if the circle was organized along orthogonal axes). Although CAM has been prevalent in the spatial cognition literature for over 20 years, mathematical properties of the model itself have not been thoroughly investigated. Also, much of the research using CAM has provided evidence for the "default" organization of categories along orthogonal axes in spatial memory, but the extent to which this is attributable to properties of the model itself is unknown. For the present project, several simulations with varying amounts of random data were used to systematically assess chance performance of different versions of CAM (i.e., representing different organizations of categories). The results suggest that (a) an orthogonal-axis version of CAM fit random data better than other versions and that (b) this effect depended in part on the distribution from which random data was drawn.

(# 31)

Inferring neural mechanisms from cognitive model parameters: Relations between the diffusion model and a spiking neural network model of perceptual decision making
Akash Umakantha, *Vanderbilt University, United States of America*, Braden A. Purcell, *New York University, United States of America*, Thomas J. Palmeri, *Vanderbilt University, United States of America* ■ According to the diffusion model (e.g., Ratcliff & Rouder, 1998), decisions are made by integrating perceptual evidence for alternative responses and selecting the response that first reaches its response boundary. These processes are implemented by relatively few parameters. Recent efforts using fMRI, EEG, and single-unit recordings have aimed to identify diffusion model parameters with specific neural mechanisms in the brain. Undoubtedly, the neural circuits underlying decision making are far more complex than diffusion model processes, so any single diffusion model parameter could potentially be implemented by many neural mechanisms. If variation in diffusion model parameters are necessary to explain behavior, then what can we conclude about variation in the underlying neural processes based on diffusion model fits? We address this question by simulating perceptual decisions using a biophysically-plausible spiking neural network model (e.g., Wang, 2002) and then fitting the diffusion model to the simulated data. We systematically test how variation of the spiking neural network mechanisms causes variation in the best-fitting parameters of the diffusion model. In some cases, the correspondence between diffusion model parameters and network parameters is clear and intuitive. Variations in in both input strength to

the network and network sensitivity are captured by variation in the mean drift rate of diffusion model accumulation. Variation in response threshold of the network is captured by variation in the diffusion model response boundary, implementing a speed-accuracy tradeoff (SAT). Surprisingly, we find that variation in the strength of recurrent excitation as well as variation in NMDA, AMPA, and GABA conductances are captured by variation in diffusion model boundary as well. This demonstrates how a single psychological phenomena, SAT, captured by a single diffusion model parameter, response boundary, can be implemented by multiple - and sometimes unanticipated - neural processes. These results inform and constrain the inferences that can be drawn regarding neural mechanisms based on diffusion model fits to behavior.

(# 32)

The list strength effect in cued recall JACK H. WILSON, *Syracuse University, United States of America*, AMY H. CRISS, *Syracuse University, United States of America* ■ The list strength effect (LSE) is a critical finding in the memory literature in part because it helped elucidate the different ways item and context information are utilized in recall and recognition tasks (e.g.: Ratcliff, Clark, & Shiffrin, 1990; Malmberg & Shiffrin, 2003). Although many studies have considered the LSE in both free recall and in recognition, fewer have considered the LSE in cued recall. The original findings of Ratcliff, Clark, and Shiffrin demonstrated a small but positive LSE for a cued recall task when word pairs were strengthened through multiple presentations and a null LSE when pairs were strengthened via study time. In a series of studies, we attempt to replicate these findings. Our findings are discussed in the framework of the REM model.

Author Index

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dmitrieva.julia.86 @mail.ru, 63
Doignon, Jean-Paul
doignon @ulb.ac.be, 37
Donkin, Chris
christopher.donkin @gmail.com, 22
Donnelly, Seamus W
sdonnelly @gc.cuny.edu, 57
Dutilh, Gilles
gilles.dutilh @unibas.ch, 46
Dzhafarov, Ehtibar
ethibar @purdue.edu, 19

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Ami.Eidels @newcastle.edu.au, 25

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jacob @ruccs.rutgers.edu, 16, 34, 48
Forget, Jacques
forget.jacques @hotmail.com, 72
Fox, Elizabeth L
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Francis, Gregory
gfrancis @purdue.edu, 38
Franklin, Anna
Anna.Franklin @sussex.ac.uk, 43
Froyen, Vicky
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Gaut, Garren Robert Joseph
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Giri, Sagun
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Glavan, Joseph James
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Gluck, Kevin A.
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Golden, Richard
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rgolman @andrew.cmu.edu, 32
Gronau, Quentin Frederik
quentingronau @web.de, 63
Gryazeva-Dobshinskaya, Vera
vdobshinya @mail.ru, 63
Gu, Hairong
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Guan, Hongyang
hongyang @uci.edu, 45
Gunzelmann, Glenn
glenn.gunzelmann @wpafb.af.mil, 39, 46
Guo, Lisa
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Hasinski, Adam E
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Helie, Sebastien
shelie @purdue.edu, 38
Hemmer, Pernille
pernille.hemmer @rutgers.edu, 24, 73, 74
Hendrickson, Andrew T.
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Hendrickson, Andrew T.
drew.hendrickson @adelaide.edu.au, 50
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wrholmes @uci.edu, 54

Hommel, Bernhard
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Houpt, Joseph W.
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Houtman, Simon
simon.houtman @gmail.com, 26
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Jacob, Jane
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Jamil, Tahira
tahjamil @gmail.com, 44
Jastrzembski, Tiffany S.
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Jay, Verkuilen
jverkuilen @gc.cuny.edu, 57
Jefferson, Brett A.
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Jones, Matt
mcj @colorado.edu, 51, 55
Jones, Michael N.
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Kılıç, Aslı
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Kachergis, George
george.kachergis @gmail.com, 60
Kato, Kenichi
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Kellen, David
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Kelly, Matthew Alexander
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Kennedy, Daniel P.
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Kharkwal, Gaurav
gaurav.kharkwal @gmail.com, 34
Kievit-Kylar, Brent
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Kim, Bommae
bommaekim @virginia.edu, 57
Kim, Seha
sehakim @rutgers.edu, 48
Kim, Sheri
sherikim @y7mail.com, 41
Kim, Sungmin
kim.2774 @buckeyemail.osu.edu, 68
Kim, Woojae
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Klauer, Karl Christoph
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Konstantinidis, Emmanouil
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Krusmark, Michael A.
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Kubovy, Michael
kubovy @virginia.edu, 15
Kunsberg, Benjamin
benjamin.kunsberg @yale.edu, 17
Kvam, Peter
kvampete @msu.edu, 25
Kwon, Tae Kyu
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Langsford, Steven
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Lee, Michael D.
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Legault, Canaan
Clegaul5 @uwo.ca, 69
Leite, Fabio
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Lerche, Veronika
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Leroux-Boudreault, Ariane
ariane.leroux.boudreault @gmail.com, 72
Li, Yunfeng
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Liu, Yanxi
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Liu, Zili
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Loewenstein, George
gl20 @andrew.cmu.edu, 32
Love, Bradley C.
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Lu, Zhong-Lin
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Luhmann, Christian C.
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Ly, Alexander
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Malejka, Simone
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Marley, Tony
ajmarley @uvic.ca, 53
Matzke, Dora
d.matzke @uva.nl, 40
McMahan, Brian
brian.mcmahan @rutgers.edu, 70
Mellers, Barbara
mellers @wharton.upenn.edu, 52
Merkle, Edgar
merklee @missouri.edu, 52
Mewhort, Douglas
mewhortd @queensu.ca, 37
Meyer, Jordan
jlmeyer @umich.edu, 71
Michie, Patricia T.
pat.michie @newcastle.edu.au, 40
Miller, Patrice Marie
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Mistry, Percy K
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Montigny, Caroline
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Morey, Candice C.
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Morey, Richard D.
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Mueller, Shane
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Myung, Jay
myung.1 @osu.edu, 44, 73

Narens, Louis
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Neufeld, Richard W.J.
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Nunez, Michael D.
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Öztekin, Ilke
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thomas.j.palmeri @vanderbilt.edu, 53, 76
Pantelis, Peter C.
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Parpart, Paula
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Perfors, Amy F.
amy.perfors @adelaide.edu.au, 29, 43, 50
Persaud, Kimele
kimele.persaud @rutgers.edu, 73
Peruggia, Mario
peruggia @stat.osu.edu, 68
Peter, Nguyen
pnguye7 @uwo.ca, 55
Pitt, Mark A.
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Pizlo, Zygmunt
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Pleskac, Timothy
pleskact @msu.edu, 25

Tjan, Bosco S.
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Friday, July 18

	Room 1 Palais	Room 2 Port-Neuf//Ste-Foy	Room 3 Courville//Montmorenc	Meeting room Lauzon
9h00 ... 10h00				
10h00 ... 10h30				
10h30 ... 12h00				
12h00 ... 13h30				
13h30 ... 15h00		2014 Professional Development ...		
15h00 ... 15h30	Coffee break (*Grande place*)			
15h30 ... 17h00		... Symposium: Negotiations		
17h00 ... 19h00	Welcoming session room Des Plaines (top floor of the Hotel)			

Saturday, July 19

	Room 1 Palais	Room 2 Port-Neuf//Ste-Foy	Room 3 Courville//Montmorenc	Meeting room Lauzon
9h00 ... 10h00	Keynote lecture: H. Barlow (*Palais*)			
10h00 ... 10h30	Coffee break (*Grande place*)			
10h30 ... 12h30	Regular session 1	IS1: Symmetry: Theory and Applications Pizlo & Singh (1/3)	Regular session 2	
12h30 ... 14h00	Lunch break (free time)			Meeting of the JMP editors
14h00 ... 15h40	Regular session 3	IS1: Symmetry: Theory and Applications Pizlo & Singh (2/3)	Regular session 4	
15h40 ... 16h00	Coffee break (*Grande place*)			
16h00 ... 17h20	Regular session 5	IS1: Symmetry: Theory and Applications Pizlo & Singh (3/3)	Regular session 6	
17h20 ... 19h00	Poster session Kent *(from 17h30 to closing)*			

Sunday, July 20

	Room 1 Palais	Room 2 Port-Neuf//Ste-Foy	Room 3 Courville//Montmorenc	Meeting room Lauzon
9h00 ... 11h00	Regular session 7	IS2: Contextualized Probability Theories Busemeyer & Wang	Regular session 8	
11h00 ... 11h30	Coffee break (*Grande place*)			
11h30 ... 12h30	Keynote lecture: R. S. Sutton (*Palais*)			
12h30 ... 14h00	Lunch break (free time)			Meeting of the SMP board executives
14h00 ... 15h40	IW: An Introduction to Gaussian Processes in Psychology; Houpt & Cox	Regular session 9	Regular session 10	
15h40 ... 16h00	Coffee break (*Grande place*)			
16h00 ... 17h30	Special conference: A crowd-sourced scheduling system for academic conferences by Joachim Vandekerckhove Business meeting (*Palais*)			
17h30 ...	Banquet at the restaurant			

Monday, July 21

	Room 1 Palais	Room 2 Port-Neuf//Ste-Foy	Room 3 Courville//Montmorenc	Meeting room Lauzon
9h00 ... 11h00	Regular session 11	IS3: The "same"-"Different" task: Things are the same 50 years later; Denis Cousineau	Regular session 12	
11h00 ... 11h30	Coffee break (*Grande place*)			
11h30 ... 12h30	Keynote lecture: W. Vanpaemel (*Palais*)			
12h30 ... 14h00	Lunch break (free time)			
14h00 ... 15h00		Regular session 13	Regular session 14	
15h00 ... 15h30	Coffee break (*Grande place*)			
15h30 ... 17h00	Closing conference: Moving past BMS and MDL: Making model evaluation rational, by Richard M. Shiffrin Closing of the conference (*Palais*)			
17h00 ... ∞				

SATURDAY (July 19th, 2014)

Time	Room: Palais	Room: Port-Neuf & Ste-Foy	Room: Courville & Montmorency
9:00	**H. Barlow:** Autocorrelation and the functional role of the visual cortex (Room: Palais)		
10:00	coffee break (Grande Place)		
10:30	**Donkin:** ROC predictions of slots and resource models of visual ...	**IS1: Pizlo & Singh** Symmetry: Theory and Applications 1/3	**Eidels:** Can bimodality distinguish serial and parallel processes?
10:50	**Mueller:** Modeling expert memory search, knowledge access...	**Liu** Computational Symmetry and Computational Regularity	**Lerche:** The role of false fixations of parameters in diffusion ...
11:10	**Malejka:** Beyond Correlated Model Fits of Continuous- ...	**Tjan** Asymmetry: what sort of perceptual quantity is it?	**van Vugt:** A model-based neuroscience approach to ...
11:30	**Cox:** Mechanisms of Recognition Memory: Insights from ...	**Tyler** A Frame-of-Reference Principle in Human Symmetry ...	**Silbert:** Using LBA to model RTs collected in the GRT paradigm
11:50	**Trueblood:** Quantum refrigerators: A quantum model of ...	**Kubovy** The Perceived Symmetry of Regular Patterns is Local	**Yu:** Individual differences in working memory capacity and ...
12:10	**Kvam:** Interference effects of choice on confidence reveal ...	(times are not synch with other sessions)	**Leite:** Modeling a modified visual search with racing diffusion ...
12:30		lunch break	(JMP Editors Meeting)
14:00	**Jefferson:** Clustering to Dimensionality, Part 1: A Simplicial ...	**IS1: Pizlo & Singh** Symmetry: Theory and Applications 2/3	**Thomas:** Decisions about decisions in the GRT can be tough ...
14:20	**Blaha:** Clustering to Dimensionality, Part 2: Uncovering Hidden ...	**Sawada** 2D images of a 3D symmetrical shape and 3D ...	**Zhang:** Subset System: Mathematical Foundation of ...
14:40	**Langsford:** Learning transformations relevant to similarity	**Dickinson** Detecting and Grouping Symmetric Parts in Cluttered ...	**Golman:** Curiosity, Information Gaps, and the Utility of Knowledge
15:00	**Schulz:** Learning functions actively- A Bayesian ...	**Froyen** Bayesian Hierarchical Grouping: A probabilistic ...	**Bhatia:** The Dynamics of Bidirectional Thought
15:20	**Speekenbrink:** Restless bandits: Exploring and exploiting ...	(times are not synch with other sessions)	**Golden:** Yet Another Stochastic Convergence Analysis of ...
15:40	coffee break (Grande Place)		
16:00	**Pantelis:** Using autonomous virtual agents for a true ...	**IS1: Pizlo & Singh** Symmetry: Theory and Applications 3/3	**Colonius:** Stochastic orders for comparing reaction time ...
16:20	**Gaut:** A Bayesian Approach to the Multiple-Label Assignment ...	**Zucker** Breaking the Symmetry in Shape from Shading	**Kelly:** The Memory Tesseract: Distributed MINERVA and the ...
16:40	**Yang:** The dynamic changes of the processing architecture ...	**Narens** Symmetry, Measurement, and the Erlanger Program	**Doignon:** Building a Learning Space on a Given Domain
17:00	**Carruthers:** Modelling human performance on the vertex cover ...	**Zhang** Perspectivity, Projectivity, and Binocular Vision	**Francis:** Modeling and design of optimal switch keyboards
17:20-19:00	**Poster Session** (Kent)		

SUNDAY (August 20th, 2014)

Time	Room: Palais	Room: Port-Neuf & Ste-Foy	Room: Courville & Montmorency
9:00	**Helie:** Automatic sequence production in the brain: A ...	**IS2: Busemeyer & Wang** Contextualized Probability Theories	**Lee:** Using Bayesian priors in psychological modeling
9:20	**Jastrzembski:** Modeling Nuances of the Spacing Effect	**Zheng** What is complementarity and compatibility in quantum ...	**Danileiko:** A wisdom of crowds approach to predicting ...
9:40	**Matzke:** A Bayesian approach for estimating the probability of ...	**Dzhafarov** Three Approaches to Making World Kolmogorovian	**Steingroever:** Bayes Factors for Reinforcement-Learning Models ...
10:00	**Alexander:** A Cognitive Psychometric Model for the ...	**Narens** The Logical Structure of Contextual Effects	**Tauber:** Inferring hypothesis spaces from generalization data
10:20	**Oddson:** The nearly null cognitive effects of relaxation and the ...	**Trueblood** A Quantum Probability Approach to Human Causal ...	**Austerweil:** Dissociating Top-down and Bottom-up Theories ...
10:40	**Smithson:** Moderator Effects in Multiple Regression: What Gets ...	(times are not synch with other sessions)	**Bartlema:** A Bayesian hierarchical mixture approach to individual ...
11:00	coffee break (Grande Place)		
11:30	**R. S. Sutton:** Reinforcement Learning and Psychology: A Personal Story (Room: Palais)		
12:30		lunch break	SMP Board of executives
14:00	**IW: Houpt & Cox** An Introduction to Gaussian Processes in ...	**Kim:** A Hierarchical Adaptive Approach to the Optimal Design ...	**Dutilh:** A sequential sampling model for explaining perceptual ...
14:20		**Jamil:** Default Bayes Factors for Contingency Tables	**Hotaling:** Testing Models of Deferred Decision Making
14:40		**Verhagen:** Bayesian Tests to Quantify the Result of a ...	**Starns:** Modeling joint recognition and source memory ...
15:00		**Guan:** Identification of publication bias through models of ...	**Kim:** A probabilistic model of 3D surface interpretation from line ...
15:20		**Tang:** Adaptive Design Optimization for Comparing Models ...	**Love:** Exploration and Exploitation: Converging ...
15:40	coffee break (Grande Place)		
16:00-16:20	**J. Vandekerckhove:** A crowd-sourced scheduling system for academic conference (Room: Palais)		
16:20-17:30	**Business Meeting** (Room: Palais)		

MONDAY (July 21st, 2014)

Time	Room: Palais	Room: Port-Neuf & Ste-Foy	Room: Courville & Montmorency
9:00	**Diederich:** Sequential sampling model for multiattribute choice ...	**IS3: Cousineau** The "same"-"different" task: Things are ...	**Visser:** The General Linear Ballistic Accumulator Model
9:20	**Singmann:** Validating the Parameters of the Dual-Source Model...	**Breitmeyer** Priming and Same-Different Tasks: Processing ...	**Terry:** Deterministic evidence accumulation models
9:40	**Hendrickson** Comparing models of inductive generalization	**Wyble:** Attentional Episodes and Comparison Operations	**Palmeri:** On making connections between cognitive models and ...
10:00	**Rubin:** An organizing framework for the comparison of semantic ...	**Davelaar** The fast-same effect and the habituation account of ...	**Holmes:** Accumulator models of decision-making under changing ...
10:20	**Parpart:** Heuristics as special cases of Bayesian inference		**Vandekerckhove:** Joint Models for Behavioral and Neural Data
10:40	**Merkle:** Using probability judgments to distinguish respondent ...		**Jones:** A theory of between-trial variability in diffusion models
11:00	coffee break (Grande Place)		
11:30	**W. Vanpaemel**: Five routes to better models of cognition (Room: Palais)		
12:30	lunch break		
14:00		**Neufeld:** Decisional Control: A Normative Model of Cognition ...	**Cousineau:** Detecting the undetectable or informing NHST of ...
14:20		**Sunehag:** Axioms for useful risk-seeking: Rationally liking both ...	**von Oertzen:** Independent Validation remedies α inflation in ...
14:40		**Luhmann:** Subjective Hazard Rates Imply Non-Stationary ...	**Donnelly:** Specification, diagnostics and interpretation of ...
15:00	coffee break (Grande Place)		
15:30	**R. M. Shiffrin**: Moving past BMS and MDL: Making model evaluation rational (Room: Palais)		
16:30	**Closing address** (Room: Palais)		