Society for Mathematical Psychology

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39^{th} Annual Meeting, Vancouver, BC

July 29 - August 1, 2006

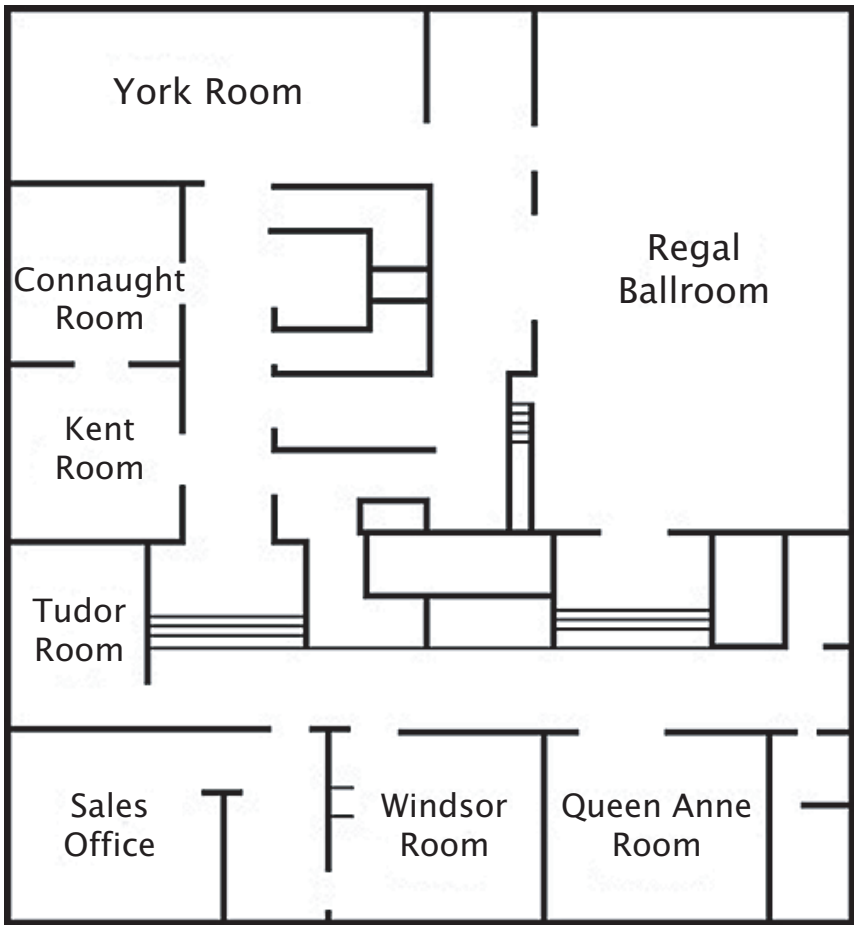
Contents

1 Conference overview

1.1 Hotel information

`Name`: Crowne Plaza Hotel Georgia
`Address`: 801 Georgia Street West, Vancouver, BC V6C 1P7, Canada
`Phone number`: (604) 682-5566

1.2 Floor plan of hotel conference rooms



All rooms are on the `Mezzanine` level, except the George Room (not shown), which is on `Level B`.

1.3 Local information

1.3.1 Map of the area

Legend

Local restaurants				
Type	Name	Price	Location	Zagat scores: food, decor, service (out of 30)
Bar/Lounge	Mahoney's	$	R	
	900 West Lounge	$$	C	
	Mosaic Bar & Grille	$$$	K	
Café/Sandwich	Gallery Café	$	F	
	Subway	$	I	
	Bellagio Café	$$	D	
	Starbucks	$$	V, Z	
Chinese	Beijing	$$	L	
French	Café Crepe	$	U	
	Bacchus	$$$	M	24, 26, 26
	Hermitage	$$$	Q	23, 20, 23
Greek	Kalypso	$$	S	
Italian	Café il Nido	$$	Y	21, 18, 21
	Caffé de Medici	$$$	T	25, 23, 27
Japanese	Tsunami Sushi	$	Q	
	Gyu	$$	P	
	Ichibankan	$$	W	
	Koji	$$	B	
	Nikko	$$	O	
Pacific Northwest	Griffins	$$	C	21, 20, 21
Seafood	Olympia Seafood Market Grille	$	X	
Steakhouse	Hy's Encore	$$	G	23, 20, 23
	Gotham Steakhouse	$$$	J	26, 25, 24
Thai	Salathai Thai	$$	N	22, 16, 20
West Coast	Chartwell	$$$	A	25, 25, 27
Other	Food Court at the Pacific Centre	$	H	
	Canadian Maple Delights	$$	E	

Amenities and resources	
Pharmacy	Blue markers
Kinko's FedEx	Green marker

1.3.2 Other attractions in the area

Name	Description	Distance	Phone
Grouse Mountain	Skyride to the top of the mountain, good views, dining, hiking and activities	About 12 km from hotel	604-980-9311
Capilano Suspension Bridge	230 feet high, 450 feet across Capilano River	About 9 km from hotel	604-985-7474
Vancouver Aquarium	Located in Stanley Park	3 km from hotel	604-659-3474
Harbor Cruises		Marina about 2 km from hotel	604-688-7246
Vancouver Lookout	Exterior glass elevator ride over 500 feet high to a 360 degree view of the city	About 1 km from hotel	604-689-0421
Dr. Sun Yat-Sen Classical Chinese Garden		About 1.5 km from hotel	604-662-3207
Science World	Science museum, good for families and children. Featured exhibition: "LEGO: Secrets of the Pharoahs", Egyptian artifacts recreated in Legos.	About 2 km from hotel	604-443-7443
Granville Island	Public market, theaters, galleries, restaurants	About 3 km from hotel	
Gastown	Historic neighborhood: restaurants, galleries, antique stores	About 1.5 km from hotel	
Robson Street	Restaurants, high-end shopping	About .5 km from hotel	

1.4 Conference schedule

Saturday, July 29

7:00-9:00 PM *Welcome Reception & Registration (York Room)*

Sunday, July 30

	Decision Processes (York Room)	***Associative Processes I*** (George Room)	***Statistics I*** (Queen Anne Room)
8:00 AM	*Human and Ideal Sequential Decision Making: Localizing the Cognitive Bottleneck* Stankiewicz & Eastman	*Phonological Similarity in Serial Recall: Constraints on Theories of Memory* Lewandowsky & Farrell	*Dependent mixture models* Visser
8:25 AM	*Paradoxes real and imagined* Shiffrin	*A gain-field model that simulates human immediate serial recall performance* Botvinick	*A Minimum Description Length Approach to Selecting among Multinomial Models of Source Monitoring* H. Wu & Myung
8:50 AM	*Modeling choice behavior in the Iowa gambling task* Wagenmakers	*Modeling Human Associative Memory* Malmberg	*Data Mining Educational Data to Discover Patterns in Student Thought* Madhyastha & Hunt
9:15 AM	*Toward a mental decision logic of the small-grand world problem in decision theory* Yang	*A SIMPLE explanation of the long-term recency effect in amnesia* Caplan et al.	*Queuing Network Modeling of Behavioral and Psychophysiological Measurements in Multitasking* C. Wu
9:40 AM	*Support Theory and Intuitionistic Logic* Narens	*Dissociating short- and long-term recency with the temporal context model* Sederberg, Howard & Kahana	*Change Detection with Identification: A Bayesian Algorithm for Sequential Analysis* Zhang
10:05 AM		*Coffee Break (Regal Ballroom)*	
	Categorization (York Room)	***Associative Processes II*** (George Room)	***Statistical Learning*** (Queen Anne Room)
10:20 AM	*Applications of Quantum Computing to Psychology* Busemeyer & Wang	*Probabilistic Topic Models for Episodic and Semantic Memory* Steyvers et al.	*Locally Bayesian learning in layers of Kalman filters* Kruschke
10:45 AM	*Knowledge Partitioning in Multiple Cue Probability Learning* Little & Lewandowsky	*Multinomial Process Tree Modeling of Age Differences in Hindsight Bias* Bayen & Erdfelder	*The dynamics of iterated learning* Griffiths
11:10 AM	*A Model of Multi-Objective Multi-Concept Formation* Matsuka, Sakamoto & Nickerson	*Mathematical Model of Spacing Effects in Memory with Applications in Education and Training* Jastrzembski	*Revealing inductive biases through intergenerational knowledge transmission* Kalish
11:35 AM	*Mixture models of categorization* Rosseel	*Context and episode in a model of human memory* Polyn, Norman & Kahana	*Simultaneous Convergence on Multiple Independent Evolving Series* Lewandowsky

12:00 PM	*Combining similarity and causality* Kemp et al.	*Toward a common model of semantic structure and episodic association* Howard, Rao & Iyer	*Stochastic Models of Judgments of Learning* Jang, Huber & Wallsten
12:30 PM	*Lunch Break*		
	JMP Editorial Board Meeting (Windsor Room)		
	Poster Setup (Regal Ballroom)		
	Symposium: Intransitivity of Preference: Revisited (Organizer: Myung) (York Room)	***Symposium: Computational Complexity Analyses of Cognitive Models*** (Organizers: van Rooij & Dror) (George Room)	
1:30 PM	*Testing transitivity of preference by a true and error model* Birnbaum	*Introduction* van Rooij & Dror	
1:55 PM	*A Bayesian re-analysis of Tversky's classic study of intransitive preferences* Iverson	*A Complexity Level Analysis of Vision: 15 years Later* Tsotsos	
2:20 PM	*Tversky's Intransitivity of Preference Revisited* Regenwetter et al.	*Neurocomputational Resources and Network Optimization* Cherniak	
2:45 PM	*Frequentist axiom testing: A generalization of Iverson & Falmagne's likelihood ratio technique* Davis-Stober	*Assessing Theories of Language Processing using Parameterized Complexity* Wareham	
3:10 PM	Myung (Discussant)	*Computing Maximum Coherence: A Hard Nut to Crack* Stege & van Rooij	
3:40 PM		*Coffee Break (Regal Ballroom)*	
4:00 PM	**Plenary I** (Regal Ballroom) **McClelland**: Graded constraint theory of the sound structure of words applied to continuous linguistic and psycholinguistic variables		
5:20-7:30 PM	*Poster Session (Regal Ballroom)*		

Monday, July 31

	Measurement I (York Room)	***Recognition Memory*** (George Room)	***Sensation and Perception*** (Queen Anne Room)
8:00 AM	*Internal Multidimensional Unfolding About a Single Ideal - A Probabilistic Solution* MacKay	*The Consequences of Differentiation in Episodic Memory: Similarity and the Strength Based Mirror Effect* Criss	*New Foundations for the Effects of Sensory Memory* Link
8:25 AM	*Deviation, Dissimilarity, Distance, and Inverse Triangle Inequalities* Dzhafarov & Colonius	*On the Mirror Effect and Signal Detection Theory: Separating Attention from Memory* DeCarlo	*A factorial hidden Markov model of perception and working memory* Huber
8:50 AM	*Regular Minimality Principle and Well-Behaved Thurstonian-type Models* Kujala & Dzhafarov	*Update on the EICL model for the mirror and spacing effects* Murdock	*Modeling the effects of payoff on response bias in a perceptual discrimination task: A further test on how four different hypotheses incorporate response biases into a sequential sampling decision process* Diederich
9:15 AM	*Learning with two estimators and a hypothesis test: distinguishing between stable and transient environments* Steele-Feldman & Anderson	*Are the data of Vitevitch and Luce (1998) a challenge for interactive activation models of word recognition?* Pitt, Myung & Altieri	*Mask-dependent cuing effects in simple visual detection: A speed-accuracy tradeoff analysis* Liu
9:40 AM	*Coffee Break (Regal Ballroom)*		
10:00 AM	**New Investigator Award** (Regal Ballroom) **Tenenbaum**: Bayesian models of inductive learning and reasoning		
	Measurement II (York Room)	***Neural I*** (George Room)	***Individual Differences / Group Processes*** (Queen Anne Room)
11:10 AM	*Audio-visual integration of letters and speech: A Fechnerian Scaling analysis* Colonius, Diederich & Dzhafarov	*Network Mechanisms for Biological Motion Recognition* Finkel et al.	*Interdependent Sampling and Social Influence* Denrell & Le Mens
11:35 AM	*On the Foundations of Measurement* Barzilai	*Simulating Color Category Evolution* Jameson, Komarova & Narens	*Group-level Findings and Individual Differences in Applied Cognitive Measurement* Neufeld
12:00 PM	*Modeling Asymmetries as Randers Spaces with Curvature* Spencer-Smith	*Biologically Plausible Models of Hebbian and Reward-Mediated Learning* Spiering & Ashby	*Measuring approximate g indexes in animals and people* Commons
12:30 PM	*Lunch Break*		
	SMP Executive Board Meeting (Tudor Room)		

	Symposium: Neural constraints on cognitive modeling (Organizer: Howard) (York Room)	***Statistics II*** (George Room)
1:30 PM	*The Neural Basis of Categorization Expertise* Ashby	*Using Population-Parameter Mapping as a Vehicle for Model Testing* Chechile
1:55 PM		*Covariance Matrix Estimation for Misspecified Models with Missing Data* Golden
2:20 PM	*A neural mechanism for decision making* Shadlen	*Prep, p-values and Bayesian Inference* Iverson, Myung & Karabatsos
2:45 PM		*A Generalization of the Mann-Whitney U Test to Factorial (Anova-Like) Designs* Miyamoto & Reaume
3:10 PM	Panel Discussion	*Sampling Mental Representations Using Markov Chain Monte Carlo* Sanborn & Griffiths
3:40 PM		*Coffee Break (Regal Ballroom)*
4:00 PM	**Plenary II** (Regal Ballroom) **Beer**: The Dynamics of Brain-Body-Environment Interaction in Evolved Model Agents	
5:20 PM		*Business Meeting (York Room)*
7:30-10:00 PM		*Banquet (Regal Ballroom)*

Tuesday, August 1

	Symposium: Problem Solving I (Organizer: Pizlo) (York Room)	***Memory models*** (George Room)	***Neural II*** (Queen Anne Room)
8:00 AM	*Group decision-making on an optimal stopping problem* Lee	*Modeling the effects of induced frequency* Nelson & Shiffrin	*Grandmother cells and information storage in the human brain* Collins
8:25 AM	*Decision time versus execution time in a multi-move optimization problem: An exploratory analysis* MacGregor	*REM-II: A model of the formation of semantic knowledge from episodic memories and episodic memories from semantic knowledge* Mueller & Shiffrin	*Locally learning joint probabilities using a new connectionist architecture* Hélie, Proulx & Lefebvre
8:50 AM	*The Convex-hull Algorithm Revisited (with Lessons for Testing Models of the Traveling Salesperson Problem)* van Rooij	*Modeling false recall: Beyond a simple associative model* Kimball, Smith & Kahana	*A Dynamic, Hebbian-style Model of Configural Learning* Blaha & Townsend
9:15 AM	*Measures of how smart people and animals are in terms of the hierarchical complexity of problems they solve* Miller	*A generalized similarity function for REM* Montenegro, Myung & Pitt	*Understanding Hidden Unit Representation in Distributed Connectionist Models* Kim
9:40 AM		*Coffee Break (Regal Ballroom)*	
	Symposium: Problem Solving II (Organizer: Pizlo) (York Room)	***Categorization and Recognition*** (George Room)	
10:00 AM	*A perceptually-driven process model of algebraic validity judgments* Landy & Goldstone	*Which one of these things is not like the others? Serial position and the von Restorff effect* Addis, Steyvers & Griffiths	
10:25 AM	*Modeling the Theory Contraction problem: A Parameterized Complexity Approach* Stege & van Rooij	*Memory operating characteristics and the ex-Gaussian distribution* Wickens	
10:50 AM	*Approximating TSP solution by Simplifying the Input with Graph Pyramids* Kropatsch, Haxhimusa & Pizlo	*A lens model approach to the study of learning in multiple cue tasks* Speekenbrink	
11:15 AM	*Non-Euclidean Traveling Salesman Problem* Pizlo, Saalweachter & Stefanov	*Finding NEMO in the brain: correlations between theta oscillations in human EEG and summed similarity* van Vugt et al.	

2 Talks

2.1 Sunday, July 30

SESSION: **Decision Processes**
ROOM: York Room
Chaired by: Eric-Jan Wagenmakers

8:00-8:25
"*Human and Ideal Sequential Decision Making: Localizing the Cognitive Bottleneck*"
Brian Stankiewicz* & Kyler Eastman
University of Texas at Austin
Most natural decision involve a sequence of decisions in which the decision maker can continually gather more information before finally declaring. The current studies investigate human behavior in a sequential decision making task involving variations of a "seek & destroy" task. In this task, participants are attempting to localize and destroy his/her opponent with noisy observations and artillery while maximizing their expected reward. We compared the human performance to that of the ideal decision maker using partially observable Markov decision processes (POMDP). Using the POMDP computed the expected reward for ideal performance and computed a ratio between the human's performance and the optimal performance (an efficiency measure). The goal of these studies was to understand the cognitive limitations preventing subjects from making optimal decisions. We tested three hypotheses: memory, probability updating and decision strategy. To test these hypotheses we provided participants with explicit information that was implicitly available in the task. Specifically, to test if the limitation was memory (remembering the actions and observations) we presented subjects with information about their actions and observations. To test if the cognitive limitation was probability updating, we provide provided explicit information about the probability of where the opponent was currently located. The results suggest that the primary cognitive limitation is in the participants' inabilities to accurately update the probabilities. When the probabilities were provided, subjects performed at 93% efficiency.

8:25-8:50
"*Paradoxes real and imagined*"
Richard Shiffrin
Indiana University
I use a variant of the 'Exchange Paradox' to motivate a discussion of the psychological basis of rationality, and the consequent appearance and actuality of paradox. To whet the reader's appetite, the paradox follows: Suppose one flips a coin until a heads appears on flip n, and places 10**(n) and 10**(n+1) dollars in each of two sealed envelopes. The envelope with the larger amount is handed to you with probability 0.8, else you are handed the other envelope. You open your envelope and observe $X. You are to either keep this amount or irrevocably exchange for the contents of the other, with the goal of maximizing expected payoff. Strangely, it can be shown that one should exchange regardless of X. It seems paradoxical to 'always' exchange what you know to be the envelope with the higher probability of having the larger amount.

8:50-9:15
"*Modeling choice behavior in the Iowa gambling task*"
Eric-Jan Wagenmakers
University of Amsterdam
The purpose of the Iowa gambling task, developed by Damasio and Bechara, is to mimic real-life decision making in an experimental context. The Iowa gambling task has recently been used to assess decision making deficiencies in several different clinical populations. Busemeyer and Stout proposed a reinforcement learning model to account for choice behavior in the Iowa gambling task. Their model incorporates three components of decision making: weighing of gains versus losses, memory for past payoffs, and response consistency. A test of specific influence demonstrates the validity of the model. Based on a large-sample study, it is argued that despite the validity of the model, care should be taken when the model is applied to clinical diagnosis on the level of the individual. Several extensions of the model are discussed.

9:15-9:40
"*Toward a mental decision logic of the small-grand world problem in decision theory*"
Yingrui Yang
Rensselaer Polytechnic Institute
Human decision making is really a two-stage process: the process of forming an appropriate decision problem and then proceeding towards its solution. Often, one needs to work between stages till a decision problem with sufficient information has been constructed. Most current decision theories focus on stage 2 decision process but neglect stage 1 decision process (Joyce, 1999); consequently, the so-called "small-grand world" problem (SGW) has remained an open question since Savage (1954). This paper proposes a formal model of the reasoning processes underlying stage 1 decision in the form of a mental decision logic (MDL) of the SGW problem, It explains how MDL works in modeling the SGW problem; the main idea is to use domain-specific mental predicate-argument structures (Braine, 1998) in transforming between the act-state structures which are commonplace to most every formal theory of decision. MDL includes a formal language and a working mechanism. An arithmetization of its dynamics through the a novel use of the Godel numbering method is also given, which shows that the resulting algebra of MDL has a ring/ideal structure. A game theoretic version of MDL is also given. For each player i, the set of possible actions Ai is treated as the set of action functions, and the product of action-sets for the other players are treated as the set of states. This model allows us to study the individual orientation in game-theoretic situations.

9:40-10:05

"*Support Theory and Intuitionistic Logic*"

Louis Narens

University of California, Irvine

Support Theory is an empirically based psychological theory designed to account for human probability judgments. Intuitionistic Logic is a logic designed to account for deductions in a famous theory of mathematics which considers mathematical entities as mental constructions. The relationship between Support Theory and a little known axiomatization of Intuitionistic Logic due to Kolmogorov is examined.

Session: **Associative Processes I**

Room: George Room

Chaired by: Sean Polyn

8:00-8:25

"*Phonological Similarity in Serial Recall: Constraints on Theories of Memory*"

Stephan Lewandowsky* & Simon Farrell

University of Western Australia (SL); University of Bristol (SF)

In short-term serial recall, similar-sounding items are remembered more poorly than items that do not sound alike. This phonological similarity effect has been observed with lists composed only of similar items as well as with lists that mix similar and dissimilar items. Early studies involving mixed lists reported that ordered recall of dissimilar items is unaffected by the presence of similar items. More recently, Farrell and Lewandowsky (2003) showed that if guessing strategies are controlled, dissimilar items on mixed lists are in fact recalled more accurately than on pure dissimilar lists, a finding that presents a considerable challenge to most current theories. We review and apply four theories of memory–Henson's SEM; Neath's Feature Model; Brown's SIMPLE; and Farrell and Lewandowsky's SOB–to the mixed-list similarity data. The simulations show that theories that relegate similarity effects to confusions at retrieval are unable to handle the results.

8:25-8:50

"*A gain-field model that simulates human immediate serial recall performance*"

Matthew Botvinick

University of Pennsylvania

Multiplicative gain modulation has been proposed as a neural mechanism for the computation of spatial coordinate transformations, scale-invariant object representations, and flexible sensorimotor mappings. Based on available neurophysiological data and previous computational observations, we propose that gain modulation may also underpin the ability to store information about serial order in short-term or working memory. To explore this hypothesis, we simulated immediate serial recall using a neural network based closely on previous models that have applied gain modulation to other processing domains. A key assumption of the model, motivated by recent single-cell recording work, was that ordinal position is encoded in a graded and log-compressed manner. The model assumed, additionally, that sequence representations are stochastic, and that they are decoded in a statistically optimal fashion. The resulting model displayed numerous benchmark features of human immediate serial recall performance, including primacy and recency effects, standard transposition gradients, effects of inter-item similarity, grouping, and prior probability, and developmental effects. In addition to establishing new contacts between neural and behavioral data, the model makes detailed predictions about serial recall performance and about neuronal response profiles.

8:50-9:15

"*Modeling Human Associative Memory*"

Kenneth Malmberg

University of South Florida

The encoding of new associations is often studied in the laboratory using an associative recognition task, whereby pairs of items that were studied together must be discriminated from pairs of items that were not studied together. Over the past 20 years or so, many models of associative recognition have been developed that fall into distinct categories. In this talk, I will describe these models and show that a package of several recent empirical findings disconfirm all of them. I will then suggest a resolution by describing a hybrid model that incorporates the assumptions of both independent cue theory and dual-process theory.

9:15-9:40

"*A SIMPLE explanation of the long-term recency effect in amnesia*"

Jeremy B. Caplan*, Deborah Talmi, Brian Richards, & Morris Moscovitch

Rotman Research Institute, Baycrest, Toronto

One of the chief arguments against two-store models of memory is the phenomenon of long term recency (LTR; Glenberg and Swanson), an advantage in free recall for late-studied items that cannot be attributed to a short-term buffer. Carlesimo and colleagues suggested that LTR was impaired in amnesics and Davelaar and colleagues used this as part of an argument that LTR is different from recency obtained in immediate free recall (IFR). However, the LTR argument relies critically on the delayed free recall condition (DFR) which was absent from the Carlesimo study. Here we consider data, including IFR, DFR and CDFR conditions, showing that amnesics exhibit all the properties of the original LTR studies (reported by Talmi et al., Society for Neuroscience abstract, 2005). Fitting amnesic and control data using Brown and colleagues' SIMPLE, which relies on positional distinctiveness in a single memory store, we ask whether dissociations are consistent with the notion that patients simply have lower performance levels. The implications for single-store models, dual-store models and hybrid models are

discussed.

9:40-10:05
"*Dissociating short- and long-term recency with the temporal context model*"
Per Sederberg*, Marc Howard, & Michael Kahana
University of Pennsylvania (PS, MK); Syracuse University (MH)
Previously, we demonstrated that a modified version of the original temporal context model (TCM, Howard & Kahana, 2002) could account for basic dissociations between short- and long-term recency in free recall without resorting to a two-store model (Davelaar et al. 2005). In this elaboration of TCM, a retrieval process consisting of a set of leaky, competitive accumulators representing the words in the list (Usher & McClelland, 2001) is sensitive to the strength of the activations at test. The accumulating dynamics give rise to a boost in recall performance that spans the last few serial positions in immediate free recall (IFR), but is not sustained beyond the last list item in continuous-distractor free recall (CDFR). Here we present fits of TCM with accumulating retrieval dynamics to additional recency dissociations, such as the persistence of short-term recency with proactive interference and reduced long-term recency in amnesics. Furthermore, we show that the elaborated TCM can capture the smaller response latencies associated with short-term recency, as well as, the smaller response latencies when recalling highly contiguous items from nearby serial positions. Thus, a short-term store may not be necessary to explain recency and contiguity effects observed in episodic memory.

Session: **Statistics I**
Room: Queen Anne Room
Chaired by: Jun Zhang

8:00-8:25
"*Dependent mixture models*"
Ingmar Visser
University of Amsterdam
In this paper I consider latent Markov models with multiple indicators (MLMM). The MLMM can be seen as a generalization of 1) the standard latent or hidden Markov model (which is typically used for univariate time series) or 2) the latent class model (which has multiple indicators but no repeated measurements). The algorithm for optimization of this model uses scaling procedures that make it suitable for modeling long time series, as against the usual EM algorithm for latent Markov models that breaks down in the face of long time series. Optimization of the model is done by a Newton type algorithm using derivatives which are also used to compute standard errors of estimated parameters. Other differences between hidden and latent Markov models will be discussed as well as extensions of the model including the option to use (time-dependent) co-variate effects on parameters. An application to time series data from a forced-choice reaction time experiment, designed to investigate the speed-accuracy trade-off, will be presented.

8:25-8:50
"*A Minimum Description Length Approach to Selecting among Multinomial Models of Source Monitoring*"
Hao Wu* & Jay Myung
Ohio State University
A family of multinomial processing tree models (MPT; Batchelder & Riefer, 1990) has been developed to analyze data from source memory experiments. The likelihood ratio test (LRT) has been used as a primary statistical tool for differentiating between MPT models that make different assumptions about the underlying cognitive processes. LRT, however, concerns primarily the number of parameters in measuring model complexity, thereby neglecting the other, potentially important, dimensions of complexity such as model structure. In contrast, the minimum description length (MDL) method considers all relevant dimensions of complexity as well as the number of parameters. In the past MDL has been successfully applied to models of categorization, information integration, and retention memory. In this presentation, we demonstrate application of MDL to the problem of selecting among MPT models of source monitoring using the data in Bayen, Murnane and Erdfelder (1996).

8:50-9:15
"*Data Mining Educational Data to Discover Patterns in Student Thought*"
Tara Madhyastha* & Earl Hunt
FACET Innovations
Modern educational practice urges teachers to find out what their students think about a topic, prior to instruction. The teacher can then tailor the instruction to the initial conceptions. These techniques are especially recommended for the teaching of science, including the delivery of computer-aided instruction. The assumption behind this approach is that students think consistently, albeit perhaps erroneously. If this assumption is correct it should be possible to identify objectively defined, consistent patterns of thinking about a problem. However there are few quantitative methods for mining student assessment data to identify concepts and the similarities between them. We present a method to compute multidimensional similarity between concepts from student responses to isomorphic questions on pre and post-assessments. These distances are then used to hierarchically cluster concepts, allowing us to understand what problematic ideas are close to the target concept and which are farther away. We compare two methods for clustering student responses to identify groups of students with similar concepts. One method is based on entropy-based clustering of student responses. The second is based on distances computed as described previously.

9:15-9:40
"*Queuing Network Modeling of Behavioral and Psy-*

chophysiological Measurements in Multitasking"
Changxu Wu
University of Michigan
Reaction time, response accuracy and psychophysiological measures such as lateralized readiness potential (LRP) have been used extensively to study information processing in dual tasks. To model these three dependent variables simultaneously in a dual task, we propose a new mathematical modeling approach–a queuing network approach based on queuing network theory of human performance (Liu, 1996, 1997) and current discoveries in neuroimage studies. This modeling approach is composed of a queuing network architecture of information processing in the brain and a set of mathematical equations in quantifying the three dependent variables in the dual task. This mathematical modeling approach can be used to account for information processing in both spatial and temporal dimensions and it provides a coherent and quantitative linkage between the neural signals (LRP) and behavioral data in the dual task. Despite its relative simplicity, this queuing network modeling approach is useful to quantify and predict behavioral performance and important aspects of the macroscopic electrical activity of the brain. Further development and extension of the current modeling approach are discussed.

9:40-10:05
"*Change Detection with Identification: A Bayesian Algorithm for Sequential Analysis*"
Jun Zhang
University of Michigan
Following Wald's seminal SPRT model on two hypotheses, traditional sequential analysis has been centered on two directions: (i) the optimal change detection problem where change-point distribution is either unknown as in the CUSUM model (Page, 1954), or assumed to be under a particular form such as geometric distribution (Shiryayev, 1963); (ii) the multi-hypothesis extension using either the likelihood ratios (Armitage, 1950) or posterior probability (Baum and Veeravalli, 1994) and an analysis of their asymptotic optimality (Dragalin et al., 1999, 2000). Here, we consider the problem of change detection along with identification in multi-hypotheses setting, assuming a known prior. A Bayesian sequential updating algorithm is proposed, along with the usual boundary-crossing stopping rule; the value of an absorbing boundary is shown to exactly equal the hit rate of a decision-maker conditioned on that response. Computer simulation reveals that the algorithm shares many similarities with human performance in stimulus detection/identification experiments.

Session: **Categorization**
Room: York Room
Chaired by: Jerome Busemeyer

10:20-10:45
"*Applications of Quantum Computing to Psychology*"
Jerome Busemeyer* & Zheng Wang
Indiana University
Quantum information processing provides a potentially important new approach to the development of architectures for cognition. On the one hand, quantum control U gates can be used to program complex sequences of condition-action transformations in the same way as production rule systems. On the other hand, superposed quantum states provide an ideal way to represent fuzzy, distributed, and uncertain information, and the matrix product of unitary operators operates like a content addressable memory commonly used in connectionist network systems. This paper provides a tutorial of quantum computing ideas and applications of quantum computing to psychologically relevant areas such as probability judgments, decision making, and conceptual behavior are reviewed.

10:45-11:10
"*Knowledge Partitioning in Multiple Cue Probability Learning*"
Daniel R. Little* & Stephan Lewandowsky
University of Western Australia
Knowledge partitioning is the idea that knowledge may be held in independent, mutually exclusive parcels. The present experiments examine the presence of knowledge partitioning in multiple-cue probability learning (MCPL), which is widely thought to be representative of real-world decision making in which cues are not perfectly predictive of outcomes. Two experiments, which varied in number of cues and the validity of cue values, found evidence of knowledge partitioning in MCPL. Knowledge partitioning in these experiments is characterized by the use of a non-relevant cue to gate which parcel is accessed. Several models of categorization, including variants of the Generalized Context Model and variants of a Cue Abstraction Model, are unable to account for the data.

11:10-11:35
"*A Model of Multi-Objective Multi-Concept Formation*"
Toshihiko Matsuka*, Yasuaki Sakamoto, & Jeffery Nickerson
Stevens Institute of Technology
A vast majority of previous computational models of high-order human cognition incorporate a type of gradient descent algorithms for their learning mechanisms and strict error minimization as the sole objective of learning. Recently, however, the validity of gradient descent as a descriptive model of real human cognitive processes has been criticized. In the present paper, we introduce a new framework for descriptive models of human learning that offers qualitatively plausible interpretations of cognitive behaviors. In particular, we apply a simple multi-objective evolutionary algorithm as a learning method for modeling human category learning, where the objective of

learning is defined not only by accuracy of knowledge, but also by subjectively and contextually defined utility of knowledge being acquired. In addition, unlike gradient descent, our model assumes that humans entertain multiple hypothesis and learn not only by modifying a single existing hypotheses but also by combining a set of hypotheses. This learning-by-combination has been empirically supported, but largely overlooked in computational modeling research. Simulation studies show that our new modeling framework successfully replicated observed phenomena.

11:35-12:00

"*Mixture models of categorization*"

Yves Rosseel
Ghent University

Mixture models of categorization are a powerful framework to study a broad range of categorization models all within a consistent framework. The key assumption of this framework is that categories are represented by a probability distribution. Mixture models are merely a flexible tool to model these probability distributions. In most applications of this framework, probability distributions are modeled by a mixture of (regularized) multivariate normal distributions, but recent applications have involved different types of distributions (multinomial, uniform, rectangular) depending on the nature of the data and the details of the model. In this presentation, I will discuss some key ingredients of these mixture classifiers in detail: the importance of regularization, the impact of adding a noise component, and the problem of choosing the number of mixture components. The presentation ends with a detailed illustration of how these models can be fitted to data collected from a typical categorization experiment.

12:00-12:25

"*Combining similarity and causality*"

Charles Kemp*, Patrick Shafto, Allison Berke, & Joshua Tenenbaum
Massachusetts Institute of Technology

Causal reasoning often succeeds even though many of the causally relevant variables are unknown. Probabilistic models of causal reasoning (Pearl, 2000) place constraints on these unknown variables — regardless of how cancer is actually caused, we can make useful inferences by assuming that smoking leads to lung cancer about 10% of the time. We argue that the effects of unknown but causally relevant variables should also be constrained by similarity. Suppose, for instance, that Bill, Bob and Fred are smokers, that Bill and Bob are identical twins, and that Bill has lung cancer. The similarity between Bill and Bob gives us more confidence that Bob will develop lung cancer than that Fred will develop lung cancer. We formalize this idea by developing a generative model for object-feature matrices that incorporates both causal relationships between features and similarity relationships between objects. The model includes previous accounts of categorization (Rehder, 2003) and property induction (Kemp and Tenenbaum, 2003) as special cases, and makes accurate quantitative predictions about several experiments where subjects combine knowledge about causal relationships between features with knowledge about similarity between biological species.

Session: **Associative Processes II**

Room: George Room
Chaired by: Mark Steyvers

10:20-10:45

"*Probabilistic Topic Models for Episodic and Semantic Memory*"

Mark Steyvers*, Tom Griffiths, Kelly Addis, & Padhraic Smyth
University of California, Irvine (MS, PS); Brown University (TG); Indiana University (KA)

Topic models take a probabilistic approach to semantic cognition and information retrieval, representing "topics" as probability distributions over words. The semantic content of a document is represented by a context-dependent probability distribution over topics. Such dimensionality-reduced "gist" based representations have been useful to understand and explain the structure of semantic networks such as word association and Roget's thesaurus. In information retrieval, these representations can lead to better retrieval performance when the search is focused on matching the content of documents irrespective of the exact words used in the search query. One limitation of gist-based representations is that they operate only at one level of abstraction and do not explain how context-specific (i.e., episodic) as well as content-specific (i.e., semantic) information can be simultaneously encoded and retrieved. Similarly, gist-based representations have limitations in information retrieval when the matching operation requires multiple levels of abstraction, at both the topic level as well as the word level. We propose a new probabilistic model that represents documents at both the topic level ("what is this document about?") and the word level ("what words are unique in this context?"). We show how this can explain Von Restorff effects in memory experiments where single unrelated words are better remembered than words fitting the gist of the list. We also illustrate how such models are useful in information retrieval, matching documents at both the topic level and a specific word level.

10:45-11:10

"*Multinomial Process Tree Modeling of Age Differences in Hindsight Bias*"

Ute J. Bayen* & Edgar Erdfelder
University of North Carolina at Chapel Hill (UB); University of Mannheim (EE)

Mathematical models are an under used tool in research on cognitive development and cognitive aging. We demonstrate the usefulness of multinomial processing tree (MPT) models

(Batchelder & Riefer, 1999) in decomposing component processes that jointly contribute to age differences in cognitive task performance. We performed a series of experiments to investigate age differences in hindsight bias. Hindsight bias is the phenomenon that after people are presented with the correct response to a question, their judgment regarding their own past response to this question is biased toward the correct response. Young and older adult participants gave numerical responses to general-knowledge questions (e.g., "When was Leonardo da Vinci born?") and later attempted to recall their own prior judgments. For some questions, the correct judgment was provided before or during recall. We used the multinomial processing tree (MPT) model by Erdfelder and Buchner (1998) to estimate parameters that represent different types of memory and judgment processes that may contribute to hindsight bias: overall recollection, recollection bias (i.e., the correct judgment impairs memory for the original judgment), and reconstruction bias (i.e., a bias to use the correct judgment to reconstruct one's own original judgment). MPT analyses showed larger recollection bias and reconstruction bias in older than younger adults when the correct judgment was in working memory during the attempt to recall the original judgment. Our analyses demonstrate how the MPT model unveils age differences in cognitive processes that are overlooked when using traditional empirical measures of hindsight bias.

11:10-11:35

"*Mathematical Model of Spacing Effects in Memory with Applications in Education and Training*"

Tiffany Jastrzembski

Air Force Research Lab, Florida State University

A great deal of research in the domain of learning and forgetting of knowledge and skill reveals that learners obtain greater gains in retention when practice is spaced further apart (Bahrick, 1987; Glenberg, 1980; Glenberg, 1979). However, the optimal spacing for practice depends on the final retention interval, with greater practice spacing providing more benefit for longer retention intervals (Glenberg, 1977; Glenberg, 1980). Pavlik and Anderson (2003; 2005) developed a computational account of this effect by modifying the existing ACT-R declarative memory activation mechanism. They linked the decay rate of an item to its activation at each practice opportunity, and added a parameter to scale the passage of time between practice sessions. The current research presents an alternative model, derived from a general performance equation that captures both the power law of practice and the power law of forgetting (Anderson & Schunn, 2000). This new mathematical model handles the spacing effect more parsimoniously than prior work (fewer free parameters), retains psychological plausibility (passage of time is unscaled), and makes predictions for future performance based on the extrapolation of mathematical regularities from known training history (rather than post-fitting and potentially over-fitting model parameters to data). The last feature provides the potential for instructors or trainers to predict a learner's performance when the training history is known, and to determine the optimal amount and spacing of training in order to achieve a desired level of performance and retention at some point in the future.

11:35-12:00

"*Context and episode in a model of human memory*"

Sean Polyn*, Kenneth Norman, & Michael Kahana

University of Pennsylvania (SP, MK); Princeton University (KN)

Parallel efforts in the memory modeling literature have led to the theoretical development of two representations, posited to reside within the human cognitive system. The first, context, is a slowly-changing representation that reflects the recent past of the system; the Temporal Context Model of Howard and Kahana (2002) shows that a simple associative model containing only an item representation and a context representation can account for much of the nuanced dynamics of free recall. The second, episode, is a representation that reflects the instantaneous state of the broader cognitive system; Norman and O'Reilly (2003), developing the Complementary Learning Systems model of McClelland, McNaughton, and O'Reilly (1995), showed that a system with such a conjunctive representation can account for data from the recognition memory literature. Here, I present an associative model of the human memory system with three interacting components: An item representation, proposed to reside in ventral temporal cortex; a context representation, proposed to reside in prefrontal cortex; and an episode representation, proposed to reside in medial temporal lobe structures (including the hippocampus). We look to the human lesion literature to drive the development of the model. Specifically, damage to prefrontal cortex and medial temporal lobe structures both disrupt memory performance, but in very different ways. We explore the ability of the model to account for performance on a variety of memory tasks in the intact system, and then explore the types of damage to the model that allow us to capture dissociations between medial temporal and prefrontal brain damage on these tasks. Specifically, we investigate the model's performance in free recall, paired-associates learning, and recency discriminations.

12:00-12:25

"*Toward a common model of semantic structure and episodic association*"

Marc Howard*, V. A. Rao, & S. V. Iyer

Syracuse University

The temporal context model (TCM) was proposed by Howard and Kahana (2002, JMP) to describe recency and contiguity, two basic properties of human memory, observed in free recall across time scales. This talk discusses several issues that have arisen in developing a model of semantic space based on TCM. TCM has the ability to explain transitive associations that are formed between items that do not co-occur in time, but that appear in similar temporal contexts. Transitive associations have been observed experimentally in the study of double-function lists of

paired-associates and are also predicted by several widely-used computational models of semantic memory. The results of preliminary efforts to construct semantic spaces by training TCM on a large corpus of text are discussed. Semantic structure also affects temporal retrieval effects from episodic memory, placing another set of constraints on a common model of semantic and episodic memory. We discuss several implications for TCM as a model of free recall if a semantic similarity is introduced into the equations for temporal context.

Session: **Statistical Learning**

Room: Queen Anne Room

Chaired by: John Kruschke

10:20-10:45

"*Locally Bayesian learning in layers of Kalman filters*"

John Kruschke

Indiana University

Consider a perceptual/cognition model that consists of a succession of Kalman filters, wherein each layer is a linear function of its input, and the parameter values have Gaussian uncertainty. When the parameter distributions of each layer are updated using locally Bayesian learning (Kruschke, in press), the behavior of the model can be quite different than when using globally Bayesian updating. Applications to human associative learning paradigms, such as highlighting and blocking, are explored.

10:45-11:10

"*The dynamics of iterated learning*"

Tom Griffiths

Brown University

Cultural transmission of information plays a central role in shaping human knowledge. Some of the most complex knowledge that people acquire, such as languages or cultural norms, can only be learned from other people, who themselves learned from previous generations. The prevalence of this process of "iterated learning" as a mode of cultural transmission raises the question of how it affects the information being transmitted. We present analyses of iterated learning under the assumption that the learners are Bayesian agents, which predict that this process should converge to an equilibrium that reflects the priors of the learners.

11:10-11:35

"*Revealing inductive biases through intergenerational knowledge transmission*"

Michael Kalish

University of Louisiana at Lafayette

The fundamental prediction of a Bayesian analysis of iterated learning is that responses should converge to the learners' prior over time. We present experiments in function and category learning that confirm this prediction. In function learning participants reveal a strong prior bias toward positive linear functions with a weaker bias toward the negative linear. In category learning participants show a bias toward one-dimensional solutions. These experiments provide an insight into the consequences of intergenerational knowledge transmission and a method for discovering the inductive biases that guide human inferences.

11:35-12:00

"*Simultaneous Convergence on Multiple Independent Evolving Series*"

Stephan Lewandowsky

University of Western Australia

Some of the most complex human knowledge, such as languages or cultural norms, can only be learned from other people, who themselves learned from previous generations. Kalish, Griffiths, and Lewandowsky (in press) recently simulated this process, known as "iterated learning," in a series of concept acquisition experiments, in which responses of participants from one generation were used as target stimuli for participants in a subsequent generation. As predicted by a Bayesian analysis (see Griffiths & Kalish, 2005), after several generations all participants converged onto the learnerss prior biases irrespective of the stimuli presented to the first generation. Here, we extend this methodology in three ways: (1) We use intra-generational (rather than inter-generational) transmission, such that peoples responses are used to derive their own subsequent stimuli. (2) Instead of learning a single concept, people in the present experiment are responding to multiple independent evolving series in a prediction task (e.g., predicting the total box office gross of a movie from its current take). (3) The actual real-world distributions of the series are known and differ from each other considerably. The data show that people are aware of the real-world distributions and use them as Bayesian priors in the prediction task. The data also show that across iterations, peoples responses converge onto the priors irrespective of the starting point. Finally, notwithstanding the diversity of priors between the various independent series, people converge onto the appropriate prior for each series.

12:00-12:25

"*Stochastic Models of Judgments of Learning*"

Yoonhee Jang*, David Huber, & Thomas Wallsten

University of California, San Diego (YJ, DH); University of Maryland, College Park (TW)

Judgments of learning (JOLs) are metacognitive responses for the probability of subsequently recalling previously studied items. The JOLs under consideration were collected with a 6-point scale under both immediate and delayed conditions, yielding separate distributions for subsequently recalled and non-recalled items in each case. Consistent with other results, delayed JOLs were more accurate than immediate JOLs. We present a family of stochastic models to account for the overall pattern of results and use it to compare various mechanisms designed to explain distribution overlap (JOL accuracy) and distribution shape (scale use). The models assume that normally distributed memory strengths underlie the JOLs and the

final recall. JOL inaccuracy is alternatively due to variability in the 6-point scale criteria and/or a change between the memory strength distributions at the times of the JOLs and of the final recall. Additional options within the family of models include the function that maps memory strength into recall, whether the criteria are symmetrical, and whether the criteria are independently sampled. While we use this family of models to test competing metacognitive theories, more generally, it is widely applicable to any situation examining the nature of confidence distributions conditioned on accuracy.

Session: **Symposium: Intransitivity of Preference: Revisited**

Room: York Room

Chaired by: Jay Myung

1:30-1:55

"*Testing Transitivity of Preference by a True and Error Model*"

Michael Birnbaum

California State University, Fullerton

Transitive models of preference assume that if A is preferred to B and B is preferred to C, then A should be preferred to C. Recent theories such as the priority heuristic model, context- and reference-dependent utility, and other models such as lexicographic semiorder and additive difference models, including regret theory, can imply systematic violations of transitivity. Renewed interest has also been recently focused on this problem from the statistical viewpoint: how does one decide whether a given rate of violation is "real" or might be due to "random" error? This talk will present a review of new experiments analyzed by means of a "true and error" model in which each choice pattern has a different rate of "true" probability and each choice has a different rate of "error." Different participants can vary in their "true" choice patterns and (in some versions of the model), different people may also have different rates of error. Among other recipes tested for violations of transitivity, Tversky's (1969) classic experiment is replicated using computerized testing procedures.

1:55-2:20

"*A Bayesian Re-analysis of Tversky's Classic Study of Intransitive Preferences*"

Geoffrey Iverson*, Jay Myung, & George Karabatsos

University of California, Irvine (GI); Ohio State University (JM); University of Illinois, Chicago (GK)

More than thirty five years ago Tversky published a now classic study of binary choice behavior that purported to show that some people, some of the time, exhibited intransitive preferences. The data were re-analyzed by Iverson & Falmagne using frequentist methods; that analysis led to conclusions that were rather at odds with Tversky. Recently, Iverson, Myung & Karabatsos have used Bayesian methods that give conclusions more in line with Tversky's original interpretation of his data.

2:20-2:45

"*Tversky's Intransitivity of Preference Revisited*"

Michel Regenwetter*, Clintin David Stober, Jason Dana, & Aeri Kim

University of Illinois at Urbana-Champaign

Transitivity of preference is a fundamental principle underlying most major rational, prescriptive and descriptive contemporary models of decision making. A transitive person, group or society that prefers choice option x to y and y to z must prefer x to z. Because of transitivity's pivotal role we investigate the property as a null hypothesis: Any claim of empirical violations of transitivity requires proof beyond a reasonable doubt. Our talk centers around a seminal paper by Tversky (1969) where he provided empirical evidence for intransitive preference in individual decision makers. We challenge Tversky's (and others') choice of empirical paradigm for investigating transitivity, question the standard operationalization of transitivity via weak stochastic transitivity and discuss methodological problems in the analysis of relevant empirical data. We use generalized mixture models, where the sample space of permissible preference states is a family of transitive binary relations (e.g., strict linear orders) and choice data are modeled as originating from a probability distribution over such a sample space.

2:45-3:10

"*Frequentist Axiom Testing: A Generalization of Iverson and Falmagne's Likelihood Ratio Technique*"

Clintin Davis-Stober

University of Illinois at Urbana-Champaign

There is a long standing disconnect between algebraic axioms of preference and the stochastic data collected to verify them (Luce & Narens, 1994). Early efforts to apply frequentist statistical methodology to algebraic axioms were limited by numerous difficulties, both computational and theoretical (Iverson & Falmagne, 1985; Iverson, 1991). Renewed interest in the problem has yielded a Bayesian methodology (Myung, Karabastos, & Iverson, 2005), but as yet the frequentist perspective has remained unresolved. This paper completes the frequentist perspective by generalizing Iverson and Falmagne's (1985) seminal work, using a likelihood ratio test to statistically analyze properly defined measurement axioms. This paper includes techniques for maximum likelihood estimation as well as derivation of the asymptotic distribution of likelihood ratio tests over a general class of inequality constraints defined by convex polytopes.

3:10-3:40

Jay Myung

Discussion of the symposium topics

SESSION: Symposium: Computational Complexity Analyses of Cognitive Models

ROOM: George Room

Chaired by: Iris van Rooij & Itiel Dror

1:30-1:55

"*Computational Complexity Analyses of Cognitive Models*"

Iris van Rooij* & Itiel Dror

Eindhoven University of Technology (IvR); University of Southampton (ID)

Computational-level analyses are often considered biologically unmotivated or irrelevant. However, such analyses can help identify theoretical constraints that must be met if we are to really understand human cognition, including if and how it can, in principle, be supported by a system like the human brain. This symposium focuses on the theoretical constraint that the brain has limited computational resources. This means that models of cognition are realistic only so far as they assume no more computational resources than the brain has available. The critical question is whether it is possible, and if so how, to assess the computational resource requirements of cognitive models? It has been argued that we can get lower bounds on the resources consumed by computational-level models by drawing on the theory of computational complexity and its associated methods for inter-model reduction. With this symposium we wish to address the following questions: Can computational resource requirements of cognitive models be assessed independently from models of brain architecture? Can computational complexity analyses of cognitive models inform models of brain architecture? Can models of brain architecture inform computational complexity analyses of cognitive models? In this symposium we put forward that the answer is 'yes' to all three questions. The contributors will illustrate these answers by presenting relevant ideas and insights from different cognitive domains.

1:55-2:20

"*A Complexity Level Analysis of Vision: 15 years Later*"

John Tsotsos

York University

The goal is to provide a theoretical foundation for the architecture and processing of visual information in the human brain. More to the point, a theoretical justification is sought for why biological vision must include attention as a basic functionality and what form does an attentive mechanism take. Since past discussions of attention always seem to involve claims of resource limitations, it is natural to look to computational complexity to see if any insights may be gained. The theory of NP-completeness is used to assess the feasibility of Visual Search, a common attentive task that is a ubiquitous functionality in biological vision. Since this problem is shown to require exponential time in its most general formulation, the brain cannot be solving this problem and instead approximations are required that re-shape this general problem so that it can be solved by the brain. In turn these implementation independent considerations constrain the kinds of mechanisms that can be implemented using neural or computer machinery and have led to a theory of visual attention with significant predictive power. This overall development will be briefly over viewed with several of the predictions that have now received significant evidence described.

2:20-2:45

"*Neurocomputational Resources and Network Optimization*"

Christopher Cherniak

University of Maryland

A bounded-resource perspective on theories in mind/brain science is by now familiar. Awareness of limitations on available resources usefully constrains models at levels of abstract operations, software, and hardware. This discussion focuses upon brain-wiring. A paradox has recently emerged: Available neural connectivity in, e.g., cerebrum, is stringently limited, yet deployment of interconnections shows very fine grained optimization. Network optimization–rather than just network satisficing–applies well to neuroconnectivity architecture. Such layout cost-minimization problems are a major hurdle of microcircuit design, and are known to be NP-complete. How are they effectively solved in biology?

2:45-3:10

"*Assessing Theories of Language Processing using Parameterized Complexity*"

Todd Wareham

Memorial University of Newfoundland

Many computationally-oriented theories for natural language processing (NLP) have been proposed over the last 50 years. A fundamental stumbling block to both implementing these theories in practical NLP systems and formulating biologically realistic versions of these theories is isolating the mechanisms responsible for computational infeasibility in such a theory. It has been shown how this can be done using classical complexity analysis. I will describe how these methods can be improved by using parameterized complexity, with particular reference to analyses of various theories of finite-state phonological processing.

3:10-3:40

"*Computing Maximum Coherence: A Hard Nut to Crack?*"

Ulrike Stege* & Iris van Rooij

University of Victoria

Maintaining a coherent belief system can be difficult. Explaining how people do it can be even harder. Many models of belief fixation run into the problem of computational intractability. This is also the case for the Coherence model put forth by Paul Thagard; the model has been proven NP-hard. In this talk we reconsider Thagard's Coherence model from a parameterized

complexity perspective. In particular, we analyze the complexity of computing the Coherence problem when parameterized by c (the number of satisfied constraints) and i (the number of unsatisfied constraints). We prove that the problem is fixed-parameter tractable for both parameters. This result presents us with a paradox: Computing a maximally coherent belief system is easy for both low levels and high levels of coherence in belief networks. Does this mean that Coherence is not so hard to compute after all?

Session: **Plenary I**

Room: Regal Ballroom

4:00-5:00

"*Graded constraint theory of the sound structure of words applied to continuous linguistic and psycholinguistic variables*"

Jay McClelland
Carnegie Mellon University

I will describe graded constraint theory of English word forms that addresses the distribution of forms in the lexicon, the goodness judgments given by native speakers of nonwords as candidate wordforms, and the pattern of errors seen in language impaired individuals including dysfluent aphasics and individuals with specific language impairment. The theory is applied to the rhymes of English monosyllabic monomorphemes (items like 'cat', 'hold' and 'clamp'). Within a template specifying possible rhymes, a number of graded constraints are identified. For example, in rhymes containing at least one stop consonant, there is a graded constraint favoring short vowels, a graded constraint favoring unvoiced vs voiced obstruents, a constraint favoring coronal articulation, and a constraint against added embellishments such as a nasal, fricative, liquid, or second stop consonant (as in 'apt'). Each constraint affects the goodness of a rhyme type in a graded, cumulative fashion. Occurrance rates of different types of rhymes in the language conform closely to the predictions of both non-parametric and parametric versions of the theory. By adding a cut-off threshold, the theory can explain with good accuracy which types of rhymes occur at all and which do not occur, although both linear and interaction terms are necessary to give a complete account. The theory also accounts well for native speaker's judgments of the relative goodness of different rhyme types and for the duration of spoken word forms – each constraint corresponds to an increase in duration. Some of the constraints also contribute to explaining the relative difficulty of forms (as indexed by error rates) for dysfluent aphasics.

2.2 Monday, July 31

Session: **Measurement I**

Room: York Room
Chaired by: Duncan Luce

8:00-8:25

"*Internal Multidimensional Unfolding About a Single Ideal: A Probabilistic Solution*"

David MacKay
Indiana University

It is commonly thought that multiple ideal objects are required when doing an internal unfolding analysis of a rectangular proximity matrix. By generalizing Coombs' concept of laterality, it is shown that a unique solution, in which one ideal distribution represents all rows of the proximity matrix, can be estimated if judgments follow a dependent sampling model. (Dependent sampling assumes that only a single draw from the ideal distribution is used for each row of the proximity matrix.) Tests for a single vs. multiple ideal solution and dependent vs. independent sampling are provided. The solution is obtained by showing that when real and ideal objects are represented by normal distributions in a multidimensional Euclidean space, each row vector of dependently sampled proximities is represented by a multivariate quadratic forms in normal variables distribution. The variance-covariance matrix of the multivariate distribution has a simple form in which the off-diagonal block covariances are either identical to the variances of the ideal objects or zero. An approximation to the PDF is developed which allows a maximum likelihood solution to be estimated. (The exact form is intractable.) Properties of the proposed model are explored and Monte Carlo simulations are used to examine recovery under a wide variety of conditions, including those where the distributional assumptions are violated. Empirical analyses are also provided.

8:25-8:50

"*Deviation, Dissimilarity, Distance, and Inverse Triangle Inequalities*"

Ehtibar Dzhafarov* & Hans Colonius
Purdue University

A new mathematical notion, dissimilarity function, allows one to construct a universal form of Fechnerian Scaling, in which the subjective (Fechnerian) distance between two stimuli is defined as the infimum of lengths of all closed finite chains of stimuli containing these two points, with the length of a chain ABCD ... being defined as the sum of dissimilarities AB+BC+CD+... between successive stimuli (following a canonical transformation of discrimination probabilities based on the Regular Minimality law). Dissimilarity may be but generally is not an oriented distance, as it does not have to satisfy the triangle inequality. The paper presents an application of this construction to spaces where it leads to Fechnerian distances which can be presented as infima of lengths of closed continuous arcs, including spaces where these infima are minima (i.e., Fechnerian geodesics exist

and are closed arcs). An interesting example of a dissimilarity function is presented by considering a stimulus space in which for every stimulus pair A and B one can find a stimulus C such that AC=CB, ACB<AB, and ACB/AB cannot fall below a specially defined function of AB.

8:50-9:15

"*Regular Minimality Principle and Well-Behaved Thurstonian-type Models*"

Janne V. Kujala* & Ehtibar N. Dzhafarov
University of Jyväskylä

The law of Regular Minimality (RM) was proposed in 2002-2003 as a candidate for a fundamental property of same-different judgments. Based on conceptually distinguishing two observation areas, the law states that (A) for every stimulus in either of the two observation areas there is the least distinguishable from it stimulus in another; and (B) if x is least distinguishable from y then y is least distinguishable from x. In addition, the level of discriminability generally varies from one pair of least distinguishable stimuli to another (the Nonconstant Self-Dissimilarity property, NCSS). The conjunction of RM and NCSS, when applied to continuous stimulus spaces, has been shown to be incompatible with well-behaved Thurstonian-type (WBTT) models. The limits of precision with which RM holds in empirical data is not, however, currently known, although the principle seems to hold well within experimental error. One cannot exclude the possibility therefore that WBTT models may provide an adequate description of discrimination probabilities while closely approximating RM. In this paper we present new theoretical results pertaining to the predicted patterns of violation of RM by WBTT models, and we present the results of fitting WBTT models of a simpler variety to experimental data.

9:15-9:40

"*Learning with two estimators and a hypothesis test: distinguishing between stable and transient environments*"

Abran Steele-Feldman* & James Anderson
University of Washington

A challenge of learning models is to represent an animal's ability to rapidly distinguish between stochastically stable and transient variations in the environment. Traditional Bush-Mosteller type learning models that maintain a single estimate of an action's reward are generally unable to fit responses in both stable and transient environments without changing the learning rate in the model. We develop a model that distinguishes stable and transient environments by maintaining both short and long term estimates of the expected rewards of actions, and then using a hypothesis test to decide which estimate to use at any given moment. The hypothesis test integrates estimates of information uncertainty and recency in a statistically justified and computationally efficient manner. Furthermore, the use of two estimators has an equivalence to recent animal studies that show associative learning involves two neural system that respond at different rates. We also show how the model provides insight into several qualitative features of operant conditioning such as spontaneous recovery and the partial reinforcement extinction effect.

Session: **Recognition Memory**

Room: George Room
Chaired by: Bennet Murdock

8:00-8:25

"*The Consequences of Differentiation in Episodic Memory: Similarity and the Strength Based Mirror Effect*"

Amy Criss
Carnegie Mellon University

When items on one list are studied longer than items on another list, the improvement in performance typically manifests as an increase in the hit rate and a decrease in the false alarm rate. This finding is referred to as the strength based mirror effect and has been accounted for by assuming that participants adopt a more strict criterion following a list containing items studied several times (e.g., Stretch & Wixted, 1998; Cary & Reder, 2003). An alternative account is found in differentiation models where longer study leads to a more accurate memory representation for the studied item (McClelland & Chappell, 1998; Shiffrin & Steyvers, 1997). The more accurate the stored representation, the less confusable it is with an unrelated foil, resulting in a decrease in the false alarm rate. Differentiation models make additional a priori predictions about reversals in FARs to foils similar to a single studied item as a function of the strength of the other unrelated study items. These predictions were empirically tested and confirmed.

8:25-8:50

"*On the Mirror Effect and Signal Detection Theory: Separating Attention from Memory*"

Lawrence DeCarlo
Teachers College, Columbia University

The conventional unequal variance signal detection theory (SDT) model is commonly used to study the mirror effect. Fit statistics and z-ROC plots for several studies of the mirror effect show, however, that the model is not fully adequate. A mixture SDT model, on the other hand, closely describes the data. The mixture SDT model potentially separates effects of attention from effects of familiarity. An analysis of data from several experiments shows that the mirror effect does not appear for fits of mixture SDT models. The results suggest that the mirror effect is due to differences in attention or levels of processing of high and low frequency words; this possibility is also shown with simulated data. A new result is also found, which is that there appears to be mixing for low frequency new words. The mixing can be interpreted as arising from a tendency to treat some low frequency new words as old words, possibly because of similarity.

The additional mixing process also accounts for results found with plurality-reversed words and rare words. The mixture SDT model provides a simple interpretation of the data and is easily theoretically motivated.

8:50-9:15

"*Update on the EICL model for the mirror and spacing effects*"

Bennet Murdock
University of Toronto

The EICL model is a three-factor model (excitation, inhibition, and context) developed to explain the mirror effect and the spacing effect. A recent study of the spacing effect (Murdock, Hockley, & Oddson, under review) gave some results that were inconsistent with the model. I hope to be able to report some improvements in the model.

9:15-9:40

"*Are the data of Vitevitch and Luce (1998) a challenge for interactive activation models of word recognition?*"

Mark Pitt*, Jay Myung, & Nickolas Altieri
Ohio State University

Vitevitch and Luce (1998) showed that spoken words with high-probability biphones are named more slowly than those with lower probability biphones. Just the opposite response pattern is found for nonwords that vary in biphone probability. To reproduce this reversal of probability as a function of lexical status, a model of spoken word recognition would seem to require not only sublexical representations, but ones that are relatively independent of lexical representations, which is how ARTphone (Grossberg, Boardman, & Cohen, 1997) is designed. This design feature of ARTphone is unusual. It is more common in models for there to be greater interdependence between levels, with sublexical representations feeding into lexical representation, as in TRACE (McClelland & Elman, 1986). We analyzed ARTphone's behavior, and a TRACE-like version of it, to learn not only whether they can mimic the empirical pattern, but also to understand how.

Session: **Sensation and Perception**

Room: York Room
Chaired by: Charles Liu

8:00-8:25

"*New Foundations for the Effects of Sensory Memory*"

Stephen Link
University of California, San Diego

Previous theoretical developments showed that Weber's Law and Weber's Constant are a natural consequence of the process of comparing sensory signals represented as Poisson Waves. A later extension showed how Poisson based opponent processes in the visual system produced the MacLeod-Boynton chromaticity dimension. Now a further extension to the effects of memory processes in psychophysical experiments provides the first measure of memory effects in units of the physical stimulus.

8:25-8:50

"*A factorial hidden Markov model of perception and working memory*"

David Huber
University of California, San Diego

In recent years, generative Bayesian belief networks have successfully characterized many information processing systems. Such models assume that conceptual representations are responsible for generating observations and that the goal of cognition is one of inference. Huber, Shiffrin, Lyle, and Ruys (2001) introduced a generative model of perceptual identification termed Responding Optimally with Unknown Sources of Evidence (ROUSE). The key mechanism within ROUSE is "explaining away" in which inference occurs between competing sources of an observation so as to reduce source confusion between primes and subsequent targets. Extending the model in time with a hidden Markov structure allows demarcation of temporal onsets and offsets as well as determination of the temporal source (i.e., a new perceptual object versus one from the immediate past). By including multiple temporal identification buffers, the new model includes the original ROUSE model, but also incorporates the ability to account for presentation dynamics, capacity limitations, and sequential effects in working memory.

8:50-9:15

"*Modeling the effects of payoff on response bias in a perceptual discrimination task: A further test on how four different hypotheses incorporate response biases into a sequential sampling decision process*"

Adele Diederich
International University Bremen

Three hypothesis, *bound–change hypothesis*, *drift-rate-change hypothesis* and *two-stage-processing hypothesis* were proposed to account for data from a perceptual discrimination task in which three different response deadlines were involved and three different payoffs were presented prior to each individual trial. It was shown how the three different hypotheses incorporate response biases into a sequential sampling decision process; how payoffs and deadlines affect choice probabilities; and the hypotheses' predictions of choice times and choice probabilities. The two-stage-processing hypothesis gave the best account, especially for the choice probabilities whereas the drift-rate-change hypothesis had problems predicting choice probabilities as a function of deadlines (Diederich & Busemeyer, 2006). Here, a further test is provided including an additional hypothesis, the mixture–of–processes hypothesis.

9:15-9:40

"*Mask-dependent cuing effects in simple visual detec-*

tion: A speed-accuracy tradeoff analysis"
Charles Liu
University of Melbourne
The detection of simple visual targets has traditionally been viewed as involving unlimited capacity, or pre-attentive, mechanisms. Challenging this view, recent spatial cuing studies suggest that detection sensitivity can indeed be enhanced by the allocation of attention. However, results of this kind can be difficult to interpret, because cuing effects could be due to spatial uncertainty rather than attention. When spatial uncertainty is eliminated, cuing effects are only observed if the target is backwardly masked (Smith, 2000). In four experiments using the response signal paradigm, we investigated the mechanisms underlying mask-dependent cuing effects in simple detection. We employed Bayesian statistical methods to estimate the magnitude of cuing effects for each individual observer in each experiment. Under unmasked conditions, cues failed to improve detection accuracy when spatial uncertainty was eliminated (Experiment 1), but large cuing effects were obtained when spatial uncertainty was present (Experiment 2). However, these cuing effects could not be directly attributed to a limited capacity mechanism. Under masked conditions, and no spatial uncertainty, stronger cuing effects were obtained with a backward pattern mask (Experiment 3), than with a simultaneous noise mask (Experiment 4), suggesting that cuing effects also depend on mask type. Overall, the results are consistent with a class of limited capacity sequential sampling models (Smith, Ratcliff, & Wolfgang, 2004; Smith & Wolfgang, 2004). We conclude with critical comments on the use of Bayes factors to choose between nested (e.g., null versus cuing effect) and non-nested models (e.g., exponential versus diffusion function). co-authors: Bradley J. Wolfgang, & Philip L. Smith

Session: **New Investigator Award**
Room: Regal Ballroom

10:00-11:00
"*Bayesian models of inductive learning and reasoning*"
Josh Tenenbaum
Massachusetts Institute of Technology
Mathematical models of high-level cognition face a tension between their theoretical goals and the reality of their subject. Our models strive for simplicity, generality, elegance, and quantitative predictive power, while people's capacities for inductive learning and reasoning appear endlessly flexible, specialized, and dependent on complex forms of knowledge that do not lend themselves to quantitative testing. The research I will describe aims to bridge this gap. We model how people learn the meanings of words or concepts, infer unobserved properties of objects, and acquire larger-scale intuitive theories, in terms of approximations to optimal statistical inference over hierarchies of structured knowledge representations.

Session: **Measurement II**
Room: Queen Anne Room
Chaired by: Ehtibar Dzhafarov

11:10-11:35
"*Audio-visual integration of letters and speech: A Fechnerian Scaling analysis*"
Hans Colonius*, Adele Diederich, & Ehtibar Dzhafarov
Oldenburg University (HC); International University Bremen (AD); Purdue University (ED)
Learning the correspondences between letters (graphemes) and speech sound units (phonemes) of a language is a crucial step in reading acquisition. Recent studies suggest that multisensory brain areas play a role in the audiovisual integration of graphemes and phonemes similar to what has been observed for the integration of speech information with lip movements. In psychophysical experiments, the simultaneous presentation of visual and auditory target graphemes and phonemes usually leads to faster reaction times and more accurate recognition and discrimination performance compared to unimodal presentations. However, not much is known about the subjective representation of graphemes and phonemes underlying these cross modal effects. Is the subjective bimodal representation simply an amalgamation of unimodal features? Or do cross modal effects suggest the existence of bimodal characteristics not present in any unimodal context? Here we present a Fechnerian Scaling analysis based on a version of the theory of dissimilarity developed by Dzhafarov and Colonius that permits a construction of subjective distances among stimuli of arbitrary complexity from their pairwise discriminability. The approach is demonstrated on data from an experiment on audio-visual integration of letters and speech.

11:35-12:00
"*On the Foundations of Measurement*"
Jonathan Barzilai
Dalhousie University
The mathematical basis for measurement in the physical and non-physical sciences has been studied since 1887, yet major problems in the classical theory of measurement have been unsolved until now. These include the problem of applicability of mathematical operations to scale values, e.g. expressions of the form m(3)=m(1)+m(2) and m(2)=5m(1) for a given mass scale. Specifically, the applicability of such expressions in the case of a fixed utility scale was not proved (nor was it claimed – it was taken for granted) by von Neumann and Morgenstern in their development of utility theory. In fact, these operations are not applicable to utility scale values or to any scale values that are based on the models of the classical theory of measurement. A new theory of measurement which addresses these problems has been developed.

12:00-12:25
"*Modeling Asymmetries as Randers Spaces with Curvature*"
Jesse Spencer-Smith
University of Illinois at Urbana-Champaign
In multidimensional scaling, asymmetries in proximity data have traditionally either been treated as noise, or have been analyzed separately from the symmetric component. More recently, there has been a heightened interest in modeling asymmetries. A natural venue for modeling asymmetric data geometrically is a class of Finsler spaces known as Randers spaces. In Randers spaces, the axiom of symmetry does not hold. A boat on a lake with a constant breeze in which the distance metric is travel time, for example, is modeled as a flat Randers surface. Recent work has characterized Randers spaces of constant curvature, providing solutions for geodesics. In general, the geodesic from point A to point B will not be the same as the geodesic from point B to point A. I describe the advantages to capturing both symmetric and asymmetric properties in a single geometric model, and outline tests to detect the presence of Randers-type asymmetries.

Session: **Neural I**
Room: George Room
Chaired by: Brian J. Spiering

11:10-11:35
"*Network Mechanisms for Biological Motion Recognition*"
Leif Finkel*, Robert Wilson, Sandhitsu Das, & Maciej Lazarewicz
University of Pennsylvania
Perception of biological motion, particularly in point-light displays, requires rapid integration of complex spatiotemporal pattern information. We report psychophysical experiments suggesting that perception of biological motion involves detecting specific "motion features", such as the characteristic movements of adjacent limbs (e.g., thigh and leg). The spatiotemporal pattern of a particular body movement can be represented as a trajectory through the space of joint angles. Recognizing a movement (walk, run, tango) corresponds to determining the motion category which best matches the trajectory. We propose a network model of biological motion recognition based on line attractor dynamics. A line attractor network can be designed to integrate angle information from multiple joints. Inputs from lower level networks representing limb positions and joint angles converge upon a higher-level network representing a particular class of movement (walk, run) and the current phase (0-360 deg) of that movement. The network determines the match to a particular movement trajectory by comparing predicted position with incoming new data. The line attractor mechanism intrinsically provides two elements of recognition: integration and prediction. Interactions between higher and lower levels are consistent with Ahissar and Hochstein's Reverse Hierarchy Theory of perception.

11:35-12:00
"*Simulating Color Category Evolution*"
Kimberly Jameson*, Natalia Komarova, & Louis Narens
University of California, Irvine
We present computational modeling results that bear on a classic controversy in psychology: The factors contributing to human color categorization across individuals and cultures (Jameson 2005). We investigated the specific processes by which shared linguistic structures like color lexicons evolve from interactions in societies of communicating agents. Previous simulation studies have evaluated some of the constraints thought to be plausible contributors to color lexicon evolution in different societies of agents (Steels & Belpaeme 2005). Like those investigations, we use evolutionary game-theory to examine the constraints appropriate for simulated individual agents (Komarova 2004), however, our simulations involve only hue categorization (rather than general color categorization) based on j.n.d. differences in stimuli (rather than on complex perceptual processing). Under these conditions we find a different pattern of results regarding robust agent-based color categorization solutions. The present findings have implications for theories of human color naming and categorization, and the formation of human semantic categories that are shared cross-culturally. REFERENCES: 1. Jameson, K. A. (2005). Culture and Cognition: What is Universal about the Representation of Color Experience? Journal of Cognition & Culture, 5, (3-4), 293-347. 2. Komarova, N. L. and Niyogi, P. (2004). Optimizing the Mutual Intelligibility of Linguistic Agents in a Shared World. Artificial Intelligence, 154, 1-42. 3.Steels, L. and Belpaeme, T. (2005). Coordinating Perceptually Grounded Categories: A Case Study for Colour. Behavioral and Brain Sciences, 28, 469-529.

12:00-12:25
"*Biologically Plausible Models of Hebbian and Reward-Mediated Learning*"
Brian J. Spiering* & F. Gregory Ashby
University of California, Santa Barbara
Biologically plausible models of Hebbian learning and reward-mediated learning are described. The model of Hebbian learning assumes that synapses between two cortical cells are strengthened if two conditions are met: 1) presynaptic activation is strong, 2) postsynaptic activation exceeds the threshold for activation of the glutamate NMDA receptor. If the postsynaptic activation falls below the NMDA threshold, then the synapse is weakened. The model of reward-mediated learning assumes that synapses between cortex and the striatum are strengthened if three conditions are met: 1) strong presynaptic activation, 2) postsynaptic activation exceeds the NMDA threshold, and 3) dopamine levels are above baseline. If one or more of these conditions is missing then the synapse is weakened. This model also specifies the exact amount of dopamine released on every

trial in response to the feedback signal (which determines the amount of strengthening and weakening that occurs). These new models are compared to standard neural network learning algorithms. For example, the ability of the reward-mediated learning model to mimic gradient descent is explored. In addition, it is shown that the known properties of dopamine release imbue this model with natural simulated annealing and cooling properties. These features allow the model to escape local minima. Other comparisons will also be made. These results provide a possible neurobiological justification for some popular neural network learning models.

Session: **Individual Differences / Group Processes**

Room: Queen Anne Room
Chaired by: Michael Lamport Commons

11:10-11:35

"*Interdependent Sampling and Social Influence*"
Jerker Denrell* & Gael Le Mens
Stanford University
Most explanations of social influence focus on how the attitudes of others provide information and signal appropriate norms. But the attitudes of others also influence the behavior of an individual. Individuals are likely to be exposed to activities that their friends enjoy. We show that such influence over sampling behavior is sufficient to produce a social influence effect. Even if the attitude of individual B only influences whether and when A gets exposed to an activity, A's attitude towards the activity will become correlated with B's attitude. Surprisingly, this occurs even if the extent to which A and B will enjoy the activity, if they engage in it, are independent random variables. To illustrate this, we develop a stochastic model of experiential learning by two individuals. The model assumes that the attitude of an individual only depends on his or her own experiences with an activity or an object. The experiences of the two individuals, if they choose to engage in an activity, are assumed to be independent random variables. Based on his or her impression each individual has to decide, in every period, whether to sample the activity again. We assume that the sampling processes of the two individuals are interdependent: the decision to sample the activity again depends on the attitudes of both individuals. Despite the fact that the two individuals have independent experiences, when they do sample, we prove that their impressions will become positively correlated.

11:35-12:00

"*Group-level Findings and Individual Differences in Applied Cognitive Measurement*"
Richard W. J. Neufeld
University of Western Ontario
A prominent issue in applied cognitive science and assessment is that of mediating findings obtained from groups to individual participants or clients. Potential mending of this hiatus is available if group-level results are amenable to mixture modeling, accommodating individual differences in performance-model properties. Allowing individual differences in cognitive performance to be an expression of randomly distributed parameter values of the task-performance model, thus composing a Bayesian prior distribution, relatively precise posterior estimates of individual parameter values become available. Moreover, precision may be retained with only modest performance samples from subsequently assessed participants, an advantage when participants may be distressed clinical patients. The procedure is applied to latencies for encoding memory-search probe items among schizophrenia and control participants, obtained under two conditions of encoding load. Mixture model assumptions are evaluated, and predictions of competing model versions are empirically assessed against each other, and against classical estimates of individuals' parameter values. A noteworthy byproduct entails an option for model evaluation based on coherence of predictive accuracy for both group and individual data.

12:00-12:25

"*Measuring approximate g indexes in animals and people*"
Michael Lamport Commons
Harvard Medical School
The behavioral sciences ultimately needs a measurement theory, allowing the comparison of performances of different species of animals. Current theories are often based on human performances and may not easily apply to other species. We propose that such a theory include three-indexes: an index of the stage of development based on the order of hierarchical complexity of the tasks the species can perform; an index of horizontal complexity; and a measure of g. Here we propose ways of conceiving of g in animals and people. We use existing research to enumerate domains, such as problem solving behavior in pursuit of food, or behaviors in pursuit of mates and/or reproduction. We then illustrate how to construct three forms of g, one across domains and one within domains.

Session: **Symposium: Neural constraints on cognitive modeling**

Room: York Room
Chaired by: Marc Howard

1:30-2:20

"*The Neural Basis of Categorization Expertise*"
Gregory F. Ashby
University of California, Santa Barbara
A biologically plausible computational model is described of how categorization expertise develops in tasks that depend on procedural learning. The model assumes there are two neural pathways from the relevant sensory association area to the premotor area that mediates response selection. A longer and slower

path, which has been described previously, is as follows: sensory association cortex – striatum – globus pallidus – thalamus – premotor area. A faster, purely cortical path projects directly from the sensory association area to the premotor area. The model assumes that the subcortical path, although slower, has greater neural plasticity, because of a dopamine-mediated learning signal from the substantia nigra. In contrast, the faster cortical-cortical path learns more slowly via (dopamine independent) classical two-factor Hebbian learning. Because of its greater plasticity, early performance is dominated by the subcortical path, but the development of expertise is characterized by a transfer of control to the faster cortical-cortical projection. The model includes differential equations that describe activation in each of the relevant brain areas, as well as a set of difference equations that describe the relevant two- and three-factor learning. A variety of simulations are described showing that the model accounts for some classic single-cell recording and behavioral results.

2:20-3:10
"*A neural mechanism for decision making*"
Michael Shadlen
University of Washington
With little sophistication, the spike rates from sensory neurons can be used to approximate useful statistics for decision-making. In the context of deciding between two sensory hypotheses, a simple difference in spike rate between sensory neurons with opposite selectivity is proportional to the log likelihood ratio in favor of one sensory interpretation over another. I will describe neural recording and stimulation experiments from the alert monkey that demonstrate that the brain uses such a difference to make decisions about the direction of motion in a 2-alternative direction discrimination task. The accumulation of this difference to threshold explains the speed and accuracy of simple decisions. A new probabilistic classification task, similar to the "weather prediction task" reveals a direct representation of log probability in parietal cortex. And, if time permits, I will explain how the brain uses elapsed time to decode such probability. I will try to relate these observations to a more general computational framework for the encoding and read out of information by neurons in neocortex.

3:10-3:40
Panel Discussion
Discussion of the symposium topics

Session: **Statistics II**
Room: George Room
Chaired by: Richard Golden

1:30-1:55
"*Using Population-Parameter Mapping as a Vehicle for Model Testing*"
Richard Chechile
Tufts University
Population-parameter mapping (PPM) (Chechile, 1998; Chechile, 2004) is a general method for estimating latent parameters for multinomial-processing trees (MPT) models. A key feature of PPM estimation is a probability measure of the coherence of the model itself, P(coh). In this paper a number of simple MPT models are studied to see the effectiveness of P(coh) measures in selecting the "correct" model. The Bayes factor decision rule is also examined for the same class of models. It is shown that a P(coh) ratio and Bayes factor ratio are not equivalent model selection metrics. Although both methods can detect the correct model, the relative success rate for the two approaches differ. In general P(coh) from the PPM method does very well as a model selection measure.

1:55-2:20
"*Covariance Matrix Estimation for Misspecified Models with Missing Data*"
Richard Golden
University of Texas at Dallas
We present the missing data problem and discuss how it is important to statistical modeling in survey data analysis, structural equation modeling, hidden Markov models, factor analysis, artificial neural networks, and hierarchical linear modeling. We then formulate the missing data problem as a maximum likelihood estimation problem and report new theoretical results concerning primitive conditions for establishing the consistency and the asymptotic distribution of the parameter estimates in the presence of missing data and model misspecification. Finally, we discuss and compare a variety of covariance matrix estimation methods for the parameter estimates in the presence of model misspecification and missing data. Specifically, single imputation, multiple imputation, stochastic expectation maximization, and Monte Carlo expectation maximization are compared within a unified framework to the maximally efficient maximum likelihood estimation approach.

2:20-2:45
"*Prep, p-values and Bayesian Inference*"
Geoffrey Iverson
University of California, Irvine
Psychological Science, the flagship journal of the Association for Psychological Science, recently advised contributors to accompany estimates of experimental effects by Prep, a measure of replicability of the sign of an effect, and to do so at the expense of the traditional p-value. However Prep is merely a proxy for the usual p-value, in its construction and in its suggested use as a decision statistic. A more telling criticism of Prep is that, being conditional on the size of an observed effect, it cannot possibly deliver on its promise to predict effect sizes obtained in replicate substantive experiments. There is good news in all of this. Once distractions like Prep are avoided, attention can be more use-

fully focused on the deficiencies of evidentiary measures such as the traditional p-value and what might replace them. Bayesian methods seem especially promising in this last respect. It is curious that Prep results from a Bayesian calculation, though not one that most Bayesians would usually contemplate.

2:45-3:10
"*A Generalization of the Mann-Whitney U Test to Factorial (Anova-Like) Designs*"
John Miyamoto* & Gregory Reaume
University of Washington
The Mann-Whitney U test is a non-parametric test for whether two samples have been drawn from the same or different populations. If p = the probability that a random observation from the first population exceeds a random observation from the second population, then it is well known that the U test can be interpreted as testing whether p = .5. Furthermore the U test yields an unbiased estimate of p. We generalize these properties of the U test to designs that contain K pairs of samples (the U test is the case where K = 1). The generalizations are analogous to tests of main effects and interactions in a K x 2 factorial anova. We show that the generalized test can be applied to response time data as in Greenwald's Implicit Attitute Test (IAT) and to judgment data in tests of utility axioms.

3:10-3:40
"*Sampling Mental Representations Using Markov Chain Monte Carlo*"
Adam Sanborn* & Thomas Griffiths
Indiana University
One of the main goals of cognitive science is to determine the content of mental representations. A natural approach to this problem is to cast mental representations as probability distributions over possible stimuli in the environment. However, ascertaining these distributions is difficult because the number of possible stimuli is huge. Researchers have historically tested hypotheses about mental representations using stimuli with only a few tightly constrained dimensions. Restricting stimulus variability in this way makes the problem feasible, but may miss important aspects of real-life mental representations. Recently, methods such as reverse correlation have been used to explore mental representations over larger spaces. Reverse correlation experiments use stimuli that are drawn randomly from the entire space, resulting in many uninformative trials. We present a new method based on Markov Chain Monte Carlo (MCMC). Using an observer's responses to stimuli, MCMC draws samples from an observer's mental representation itself. This method excels when most of a distribution's probability is concentrated in a small region of the space. Thus, a large number of possible stimuli can be considered, and relatively few trials need to be used. We test this method by sampling from peoples mental representations of the shape of different kinds of animals.

SESSION: **Plenary II**
ROOM: Regal Ballroom

4:00-5:00
"*The Dynamics of Brain-Body-Environment Interaction in Evolved Model Agents*"
Randall Beer
Case Western Reserve University
Attempts to understand the neural mechanisms of behavior face many difficulties. Chief among these is a theoretical one: How can we understand the counterintuitive organizations that evolution often produces, especially when they consist of densely interconnected networks of nonlinear dynamical elements embodied in a complicated biomechanical periphery and situated in a complex natural environment? One approach to these difficulties is the careful study of idealized models of complete brain-body-environment systems. Specifically, we use genetic algorithms to evolve dynamical "nervous systems" for model agents, and then analyze in detail the operation of these evolved agents using the tools of dynamical systems theory. In this talk, I will briefly describe a series of experiments on visually-guided behavior, including object orientation, object discrimination, catching, short-term memory and selective attention. The majority of the talk will then focus on the detailed analysis of an evolved object discrimination agent. This agent foveates and actively scans objects as they near before deciding whether to approach or avoid them. Psychophysical studies are used to explore the object features used in the discrimination and the way in which the decision is made. Then an analysis of the underlying dynamics of the coupled agent-environment system is undertaken. This analysis explains several features of the agent's behavior and makes a number of qualitative predictions that have been subsequently verified. More fundamentally, it illustrates some of the implications and challenges of taking a dynamical perspective on more sophisticated behavior.

2.3 Tuesday, August 1

SESSION: **Symposium: Problem Solving I**
ROOM: York Room
Chaired by: Zygmunt Pizlo

8:00-8:25
"*Group decision-making on an optimal stopping problem*"
Michael Lee
University of California, Irvine
We consider how groups of people make decision for an optimal stopping problem sometimes known as the "Secretary Problem". The problem involves a list of numbers that are shown one at a time. The goal is to choose the maximum number, under the constraint that it must chosen at the time it is presented. We tested how groups of five people make decisions on this

problem. Using a networked set of computers, each person saw the next number in the problem individually, and then made a recommendation about whether or not it should be chosen. Following all recommendations being cast, everybody was shown the recommendations of the other group members, and given the opportunity to revise their recommendation. Using the final recommendations, we considered three scenarios for group decision-making. In the first scenario, the majority of group members had to recommend choosing a number for it to become the group choice. In the second scenario, all of the group members had to recommend a number as the consensus choice. In the third scenario, a leader was appointed, whose recommendation became the group choice. We present some analysis of the empirical results, considering previous models of how individuals make decisions on this task, and using a Bayesian hierarchical signal detection model to identify bias shifts in choices resulting from the different group decision-making scenarios. One surprising finding is that, while seeing the divergent opinions of others has relatively little effect on decision-making, the mere fact that decision-making is occurring in a group setting does seem to make people behave differently from the way they did individually.

8:25-8:50

"*Decision time versus execution time in a multi-move optimization problem: An exploratory analysis*"

James MacGregor
University of Victoria, Canada

Over the last ten years there has been growing interest in how people solve instances of intractable combinatorial optimization problems, such as the planar version of the "traveling salesman problem" (TSP). For smaller problem instances, (<=20 nodes) the solutions of untrained adults are typically at or close to optimal. Thereafter, performance declines slowly with increasing numbers of nodes (n). People generate solutions quite quickly, typically requiring less than one minute for a twenty-node problem. There are some indications that solution times are linear in n, which could be an important finding, since effective computational heuristic procedures are typically less efficient than this. However, as currently measured, solution time includes the execution time involved in physically drawing a line or moving a cursor. If execution time constitutes a large component of total solution time, then it remains unclear how the decision time component varies with n. The paper proposes a procedure for decomposing solution times into execution and decision components. It also presents some preliminary findings, which suggest that decision time per node may increase with n. That is, human TSP decision times may be poorer than linear in n. The paper discusses additional implications of the results for the nature of human solution processes.

8:50-9:15

"*The Convex-hull Algorithm Revisited (with Lessons for Testing Models of the Traveling Salesperson Problem)*"

Iris van Rooij
Eindhoven University of Technology

The convex-hull algorithm proposed by MacGregor, Ormerod, and Chronicle (2000) is one of the main competitor models of human performance on the Traveling Salesperson problem (TSP). In this talk, we reconsider this model and its purported fit to human performance data. First, we argue that MacGregor et al. failed to put their convex-hull algorithm to a critical test, because they compared human and model performance for randomly selected point sets using tour length as a dependent measure. Second, we present new results that compare human and model performance for critical point sets using tour shape as a dependent measure. These new results reveal a qualitative misfit between human and model performance. We discuss some of the methodological lessons that can be drawn from our work for testing computational models of TSP performance in general.

9:15-9:40

"*Measures of how smart people and animals are in terms of the hierarchical complexity of problems they solve*"

Patrice Marie Miller
Harvard Medical School

A problem in comparative psychology is the lack of good way to compare "how smart" different animals are in solving problems. Here, we set forth a general and powerful means. The Model of Hierarchical Complexity (MHC) posits that problems can be ordered as to their hierarchical complexity. The Model also may measure the stages of behavior on this absolute scale. It does so by taking the problem solving actions that animals and humans engage in, and ordering them. Stage of performance has the same number and name as the corresponding order of hierarchical complexity of the problem it correctly completes. Animal species and people are characterized by the highest stage of performance observed with any amount of training on their best task series. Animals perform up to the concrete stage, about what 8 to 10-year-old children do. Examples show how the Model of Hierarchical Complexity can be used to compare how smart different animals and people are.

Session: **Memory models**

Room: George Room
Chaired by: Thomas Griffiths

8:00-8:25

"*Modeling the effects of induced frequency*"

Angela Nelson* & Richard Shiffrin
Indiana University

In a study by Nelson and Shiffrin, it was shown that differential training in a visual search task of novel Chinese characters produced frequency effects in subsequent perception and memory tasks. One model of frequency effects, the REM model of

Shiffrin and Steyvers (1997), is inappropriate in several respects: REM assumes both that 1) higher frequency items are composed of higher frequency features, and 2) that higher frequency items share more features with each other than do low frequency items. Since our Chinese characters were randomly assigned to training-frequency, the second assumption is not reasonable. We developed an alternative version of REM appropriate for our task. It assumes unique features for each character presented, so that the feature base rates induced by training will match the training frequencies. For subsequent memory and perception tasks, we use a REM-like Bayesian fuzzy-matching process: Each feature of the item being encoded is either copied correctly with a probability that depends on base rate, or is stored randomly. What is stored is an imprecise representation, with the system deciding a feature of a test alternative 'matches' if that feature is within some tolerance limit of similarity to the stored representation. The system reaches a Bayesian decision on the basis of the matches and mismatches noted when one or more alternatives are compared to the fuzzy percept. This model is shown to fit the results of perceptual identification, episodic recognition memory, and pseudo-lexical decision.

8:25-8:50

"*REM-II: A model of the formation of semantic knowledge from episodic memories and episodic memories from semantic knowledge*"

Shane Mueller* & Richard Shiffrin
Indiana University

Episodic memories form through the interpretation of events by semantic knowledge, while semantic knowledge forms by the accumulation of information from episodic memories. Through this two-way process, our extensive episodic memory for events in the past co-evolves with our vast knowledge about the world. We present REM-II, a new Bayesian account of episodic and semantic memory that explicitly models the development of these two aspects of our long-term memory. REM-II encodes episodic traces as sets of features with different values, and semantic knowledge as a set of co-occurrences of these features, while assuming that co-occurrence of concepts allows for relational and semantic similarity to emerge. The use of feature co-occurrence allows polysemy and connotation of meaning to be encoded within a single structure, based on the distinct contexts in which a concept appears. We demonstrate knowledge formation in REM-II and show the emergence of semantic spaces through experience and the resultant polysemy and biasing of encoding that REM-II produces. The model is also able to use these representations directly to perform typical laboratory memory tasks, providing accounts of frequency effects in recognition memory and recall patterns in free recall.

8:50-9:15

"*Modeling false recall: Beyond a simple associative model*"

Daniel Kimball*, Troy Smith, & Michael Kahana
University of Texas at Arlington (DK, TS); University of Pennsylvania (MK)

We present a new theory of false memory that builds on existing computational models of veridical memory. In the Deese-Roediger-McDermott (DRM) paradigm, an unstudied critical word is often intruded during recall of a list comprised of its strongest semantic associates. However, extra-list and prior-list intrusions are comparatively rare. Our model, fSAM, builds on a recent version of the Search of Associative Memory (SAM) model of veridical recall (Sirotin, Kimball, & Kahana, 2005), which simulated the effects on free recall of prior semantic knowledge and episodic experience. We show that the SAM model alone cannot simulate the intricate pattern of intrusions and veridical recall observed for lists that vary in the degree of semantic association among words on the same list, among words from different lists, and between studied list and an unstudied critical word. To account for this pattern, fSAM employs two key mechanisms. During encoding, the strength of association between each word in the lexicon and list context is increased in proportion to the word's combined strength of semantic association to all words that are jointly rehearsed at a given time. During retrieval, a word is accorded preference in proportion to its combined strength of semantic association to all of the most recently recalled words. Each mechanism succeeded in simulating a substantial portion of the data well, and both mechanisms together fit the data well globally.

9:15-9:40

"*A generalized similarity function for REM*"

Maximiliano Montenegro*, Jay Myung, & Mark Pitt
Ohio State University

REM (Retrieving Effectively from Memory; Shiffrin & Steyvers, 1997) is a recognition memory model that calculates similarity between a probe item and traces in memory as the average likelihood ratio across all memory traces. We present a Minkowski-metric-like extension of this similarity function that enables one to explore the value of using different averaging modes (e.g., arithmetic, geometric, harmonic) by varying the value of the metric parameter r. In this generalized expression, REM can be seen as a member of a family of models (obtained when r = 1), whose performance can be compared with variants differing only in r. A geometric version of the model (GREM) is obtained when r = 0. We show that GREM shares many characteristics with the original REM but with much simpler expressions, overcoming the vexing issue of computational feasibility that has hindered larger-scale simulations of the model.

Session: **Neural II**

Room: Queen Anne Room
Chaired by: Leslie Blaha

8:00-8:25

"*Grandmother cells and information storage in the human brain*"

John Collins

Penn State University

Quian Quiroga et al. [Nature 435, 1102 (2005)] have recently discovered neurons in human subjects (in areas like the hippocampus) that appear to have the characteristics of grandmother (GM) cells. This is in stark contrast to the conventional view (textbooks and courses) that GM cells are biologically impossible, and that instead high level percepts and memories must have a distributed representation, across many neurons. Without a correct answer one cannot expect to have a correct understanding of how brains work. Experiments only give data on such a limited set of neurons and stimuli that additional theoretical reasoning is needed. I will explain that, contrary to the general impression, a GM-cell representation can be optimally efficient, but that it is necessarily accompanied by a population of cells giving a conventional distributed representation of the input. From the data I show that only about 5% of the cells are in the distributed-code population, and that the number of categories coded by the detected GM-like cells is less than 4200. This is rather low for them to be classic GM cells, unless there are certain plausible biases in cell selection. A natural alternative is that they are GM-like cells coding for explicit memories. I will discuss the strong consequences both for the architecture of neural systems and for the statistics of neural firing and the patterns of synaptic connectivity.

8:25-8:50

"*Locally learning joint probabilities using a new connectionist architecture*"

Sebastien Hélie*, Robert Proulx, & Bernard Lefebvre

Univérsite du Québec à Montreal

Extracting redundancies in the data is the main purpose of unsupervised learning and estimating the covariance using Hebbian learning is a widespread way to achieve this. However, Hebbian learning only leads to the extraction of between-unit covariance and, because most associative memories are using distributed representations, extracting the covariance of states would be more useful. Yet, this operation would still be insufficient to fully model complex environments, which include higher-order (non-linearly separable) relations such as causal chains (including indirect causal factors) and the exclusive-OR categorization problem. In this presentation, we propose the Joint Probability EXtractor (JPEX), a new hybrid competitive / associative connectionist model that extracts higher-order joint probabilities of the network's states. At the competitive level, several independent receptive fields are summarizing their individual states using standard winner-take-all learning. At the associative level, each receptive field's output layer is connected to the next in a serial manner. Hence, the complete joint frequency distribution of the output layers is learned using the tensor product to adjust the weights included in an associative tensor. In order to evaluate the performance of this new learning rule, it is compared with simple Hebbian learning in a density estimation problem and a hetero-associative learning problem. In the first simulation, only JPEX can detect the second-order relations included in the environmental density and JPEX's reconstitution of the density does not differ from the learning environment according to the G2 statistic. The second simulation shows JPEX's ability to rapidly learn the XOR categorization problem.

8:50-9:15

"*A Dynamic, Hebbian-style Model of Configural Learning*"

Leslie Blaha* & James Townsend

Indiana University

Configural learning is the process of developing a configural or holistic visual object representation. Experimental findings (Blaha & Townsend, in preparation) support the process of perceptual unitization as a potential mechanism underlying configural learning; such a process has the potential to support the development of configural face processing mechanisms. Capacity models of the configural learning process indicate that processing is initially a slow, limited capacity process, with work-load efficiency improving over learning to extreme super capacity processing. This qualitative shift in processing is commensurate with the configural information processing model proposed by Wenger and Townsend (2001): interactive parallel processing with facilitatory channel interactions resulting in super capacity processing. To capture this learning process, we constructed a Hebbian-style learning model, employing a recursive learning rule to develop processing channel interactions within a parallel linear system. Simulations exhibit a qualitative shift in capacity measures from extreme limited to extreme super capacity by transforming negative (inhibitory) cross-talk parameters into positive (facilitatory) interactions. This qualitative shift can also be captured by a learning model which incorporates a change in processing architecture from a slow, serial to a fast, parallel system. Implications for distinguishing model differences via further experimental work are discussed.

9:15-9:40

"*Understanding Hidden Unit Representation in Distributed Connectionist Models*"

Woojae Kim

Ohio State University

Distributed connectionist models are a popular tool for studying cognition, especially language processes. Although there have been many demonstrations of the explanatory power and flexibility that can arise from a small set of processing principles, detailed behavioral analysis of the learning processing and the resulting hidden-layer representations has been difficult to perform. Methods such as cluster analysis can be informative but are limited in applicability and informativeness. In this paper, a new methodology for examining the internal representations

of distributed connectionist models is developed. The study investigates a method for analyzing the relationship between purposely selected patterns of model behavior and their corresponding distribution of hidden unit activations. A PDP model for English word reading, developed by Plaut, McClelland, Seidenberg, and Patterson (1996), is dissected using the method. The results give some insights into how the model performs the task it has been taught, by revealing the structure (i.e., representation) and functioning of its hidden layer. Particularly, the study focuses on the model's so-called quasi-regular behavior, a central issue in language processing.

Session: **Symposium: Problem Solving II**

Room: York Room
Chaired by: Zygmunt Pizlo

10:00-10:25

"*A perceptually-driven process model of algebraic validity judgments*"

David Landy* & Robert L. Goldstone
Indiana University

We present a computational simulation of human performance on a basic validity task (the verification of equality of two sides of a potential equation), and two experiments which explore predictions the model makes about the role of visual layout in rule-based syntactic judgments. In this model, rich perceptual grouping processes implement directly much of what is traditionally seen as amodal mathematical knowledge. In the experiments, participants judged the validity of a set of equations which tested their ability to apply the order of operations rules (multiplication precedes addition). Various non-mathematical grouping pressures were manipulated so as to be compatible or incompatible with the mathematical rule. Accuracy was highest when the non-mathematical pressure supported the formal grouping rule. The increase was significantly greater when the correct judgment depended on the order of operator precedence, and persisted in the face of prior instruction and feedback. In a production experiment, participants wrote symbolic versions of provided word equations; distances between addends and multiplicands were measured. The results indicated that reasoners generate physical environments that align perceptual and mathematical groups, by separating mathematically distinct entities. The importance and apparent centrality of physical segmentation and grouping to validity judgments in algebra is at odds with traditional computational approaches to mathematical reasoning, which generally assume that the role of perception in reasoning is the transmission of symbols to an amodal processing system; we'll discuss some implications of the empirical results for these existing computational approaches.

10:25-10:50

"*Modeling the Theory Contraction problem: A Parameterized Complexity Approach*"

Ulrike Stege* & Iris van Rooij
University of Victoria (US); Eindhoven University of Technology (IvR)

Revising beliefs and theories in light of new evidence is a central aspect of human scientific thinking. A rational scientist, so it seems, would not give up beliefs she previously held, unless the new evidence forces her to do so. But this presents an inferential problem: If one's belief system implies p, but new evidence falsifies p, how can one change one's belief system while giving up no more beliefs than necessary? In his seminal 1994 article "Changing the Theory of Theory Change: Towards a Computational Approach", Tennant set out to devise a new model of this problem, called Theory Contraction, with the main objective that it would yield a computationally realistic characterization of belief revision so construed. In 2003, Tennant proved that Theory Contraction is NP-complete. Even though this means that the model is indeed computable, since the problem is in the class NP, it also suggests that no efficient (i.e., polynomial-time) algorithm exists for solving it, because the problem is NP-hard. In other words, Tennant has brought us only half way by presenting a computable yet intractable characterization of belief revision. In this talk, we show how parameterized complexity theory can lend a helping hand. We reconsider Tennant's NP-completeness proof from a parameterized complexity perspective and show that a number of the special cases that are intractable on Tennant's analysis afford efficient computation by tractable fixed-parameter algorithms.

10:50-11:15

"*Approximating TSP solution by Simplifying the Input with Graph Pyramids*"

Walter G. Kropatsch, Yll Haxhimusa*, & Zygmunt Pizlo
Vienna University of Technology (WK, YH), Purdue University (ZP)

The traveling salesperson (TSP) finds the shortest tour through n cities. It is known that this problem is difficult to solve when the number of cities is large, in fact IT is NP-hard. In spite of this, there exist configurations of cities where a trivial closest neighbor connecting algorithm finds the optimal solution. Instead of finding the solution of the input with a large number of cities, the problem is first approximated into a simpler form containing smaller number of cities, which is then solved optimally. Pyramid solution strategies in a bottom-up way convert a 2D Euclidean TSP problem with a large number of cities into successively smaller problems with similar layout and solution until the number of cities is small enough to seek the optimal solution. Expanding this solution in a top-down manner to the lower levels of the pyramid approximates the solution. Regular pyramids lack shift invariance, thus by shifting the input different solutions are produced. An irregular dual graph pyramid adapts its structure to the data and is shift invariant. It is known that the length of the minimal spanning tree (MST) is lower bound of

the length of the shortest TSP tour. Christofiedes (1976) used MST to produce an approximating TSP solution with the upper bound 3/2 shortest TSP tour. A version of Boruvca's MST construction will be applied to the solution of the TSP problem. Inserting further cities along the optimal tour does not change its length. This increases the size of a given TSP problem into a large class where the trivial algorithm finds the original optimal solution. This may be of interest for two reasons: 1) it allows the generation of a large variety of new problems with a known optimal solution. 2) The difficulty of a given TSP problem could be related TO the density of cities along the optimal tour. A closest point algorithm will be applied to generate classes of new TSP problem with known solution. (We kindly acknowledge the support of FSP-S9103-N04, FWF-P18716-N13, and Air Force Office of Scientific Research)

11:15-11:40

"*Non-Euclidean Traveling Salesman Problem*"

Zygmunt Pizlo*, John Saalweachter, & Emil Stefanov

Purdue University

It is quite well established that humans can produce very good solutions to a Traveling Salesman Problem when the cities reside on a Euclidean plane (E-TSP). They solve the problem "visually." According to our model they first perform hierarchical clustering, followed by a coarse-to-fine process of tour approximations. The clustering operations and building the tour are based on the assumption that the plane is Euclidean. In order to test the generality of the model, we tested humans with TSP on a Euclidean plane in the presence of obstacles. Obstacles change the metric, so the problem is no longer E-TSP. Problems with obstacles are only slightly more difficult than E-TSP problems, as long as the obstacles are geometrically simple (straight-line segments). With such obstacles the visual system seems to perform clustering by ignoring obstacles. The information about obstacles is used only at the stage of building tour approximations. Producing a tour involves solving the shortest path problem. This is done in the model by using the visibility graph followed by a standard shortest path algorithm. This new model provides a good fit to the psychophysical data.

Session: **Categorization and Recognition**

Room: George Room

Chaired by: Marieke van Vugt

10:00-10:25

"*Which one of these things is not like the others? Serial position and the von Restorff effect.*"

Kelly Addis*, Mark Steyvers, & Tom Griffiths

Indiana University (KA); University of California, Irvine (MS); Brown University (TG)

While much empirical work has focused on the relation of semantic knowledge and episodic memory, the link between models of semantic knowledge and models of episodic memory has largely been ignored. The von Restorff effect, increased memory for a single unrelated item presented among a series of related items, provides an ideal memory paradigm to forge such a link. Here we present behavioral data from two recall experiments using lists of semantically-related items that contain a single unrelated item. The serial position of the unrelated item is manipulated across lists. Results indicate that the unrelated item shows a recall advantage relative to control items across all serial positions when it is the first item recalled at test. When it is not output first, the unrelated item only shows increased recall for later serial positions. To interpret this complex pattern of recall dynamics, we turn to a model that accounts for both the semantic similarity among items and the differentiation of the unrelated item. The topics model is a probabilistic model of semantic space that represents the "gist" of a list in an episodic memory task as a probability distribution over topics. A recent extension of this model represents lists at both the "gist" level and the individual word level. By representing the related list words at the "gist" level and the unrelated word at the word level, this new model easily predicts the von Restorff effect.

10:25-10:50

"*Memory operating characteristics and the ex-Gaussian distribution*"

Thomas D. Wickens

University of California, Berkeley

Results from memory research suggest that certain recognition memory results cannot be described by operating characteristics based on either Gaussian or finite state models. However, systematic fitting and testing procedures, such as those available for the older models are not available. This talk explores the use of the ex-Gaussian distribution as a tractable and more general alternative to the Gaussian models.

10:50-11:15

"*A lens model approach to the study of learning in multiple cue tasks*"

Maarten Speekenbrink

University College London

In this paper, we propose a dynamic lens model approach to study learning behaviour in multiple cue probability learning tasks. In this class of probabilistic category learning tasks, the objective is to predict the value of a criterion (the category) on the basis of a number of cues (the stimuli or stimulus dimensions). The lens model approach, which has been very successful in judgment analysis, consists of applying the same model to two sets of data, one comprising the cues and criterion, and one comprising the cues and response (the predictions). The parameters of the two models are then compared. Our dynamical lens model describes criterion and response through a progression of parameter estimates over the trial sequence. As such, it offers a fine-grained analysis of individual learning behavior.

A main advantage of the method is that it provides a precise way of modeling (sub)optimal categorization behavior through the differences between an individual's subjective cue utilization and the objective cue validity in the task environment. Other advantages of the approach include the possibility to investigate distinctions in learning and response process, as well as offering a different way to assess empirical fit of different learning models. An application to an experiment comparing the learning behaviour of amnesic and control subjects is presented.

11:15-11:40

"*Finding NEMO in the brain: correlations between theta oscillations in human EEG and summed similarity*"

Marieke van Vugt*, Robert Sekuler, Hugh Wilson, & Michael Kahana

University of Pennsylvania (MvV, MK); Brandeis University (RS); York University (HW)

We examined subjects' electroencephalographical (EEG) activity as they studied and maintained short lists of visual stimuli (faces or gratings) for an immediate recognition memory test (Sternberg, 1966). Computational models of this task (e.g., Kahana & Sekuler, 2002) hypothesize that recognition memory judgments are based on the summed similarity of the test item with each of the items in the study list. We sought to characterize the electrophysiological correlates of this summed similarity computation. Summed similarity correlated with oscillatory activity mainly during different time bins in the 1000 ms interval following the presentation of the test item, most notably in frontal and parietal regions (around 400 ms post-probe). These effects appear mainly in the theta (4-8 Hz) bands, and are consistent with the idea that brain oscillations reflect aspects of the summed similarity computation. More generally, this study shows how mathematical modeling of behavior and EEG analysis can be combined to explain cognition.

3 Posters

3.1 Sunday, July 30

SESSION: **Poster session**
ROOM: Regal Ballroom
5:20-7:30

"*Multifractal Structure of Head Movements during Conversation*"
Kathleen Ashenfelter*, Jennifer Waddell, Nikolay Vitanov, & Steven Boker
University of Notre Dame (KA, SB); Augustana College (JW); Bulgarian Academy of Sciences (NV)
Nonverbal behaviors that accompany discourse in face-to-face conversational interactions are a vital component of the human communication process. The current research investigated the multifractality of angular head movement velocity from computerized motion tracking of participants engaged in dyadic conversation and its predictability due to the gender and self-reported dominance score of the participants. Motion-tracking equipment was used to record head movements during conversations between pairs of participants engaging in a mock job interview. Each pair consisted of one high-dominance and one low-dominance participant, where the interviewer was always the interviewer in order to reinforce the manipulated asymmetry in dominance. Wavelet Transform Modulus Maxima (WTMM), a multifractal analysis using wavelet transforms, was applied to these data. Wavelet transforms were chosen for this analysis because they efficiently extract localized periodic structure from nonstationary data. Results indicate a multifractal structure for angular head velocity. When interpreting the tau(q) plots produced by the WTMM for these data, the Holder exponent for negative q (or small-scale fluctuations in the time series) appears to be persistent (> 0.5) and antipersistent (< 0.5) for positive q (small-scale fluctuations). Additionally, dominance and sex of the participant are found to be independently related to the multifractal structure of head movements. Implications for finding separate fractal scaling for large- and small-scale fluctuations in the angular velocity of head movements are discussed.

"*A Response-Time Approach to Comparing Generalized Rational and Take-the-Best Models of Decision Making*"
Bryan Bergert* & Robert Nosofsky
Indiana University
Lee and Cummins (2004) compared two models of decision making in a task of paired-comparison multiattribute inference: the single-cue Take-the-Best decision algorithm (TTB), and the "rational" linear summation of evidence (RAT). First, we extend these models into more general, psychologically plausible forms that allow for subjective feature weights and probabilistic responding. Second, we replicate Lee and Cummins's experiment and demonstrate improved fits from the general models. Third, we observe a formal identity between the general versions of TTB and RAT. However, consideration of the best-fitting feature weights suggests that the vast majority of participants adopted a strategy that is more in the spirit of the TTB approach. Finally, we introduce response-time experiments that provide converging evidence for the prevalence of the generalized TTB approach under the present experimental conditions.

"*What is controlled in the Eriksen conflict task? Distributional analyses of computational models.*"
Eddy Davelaar
University of Maryland, College Park
The Eriksen flanker task has been used in a variety of neuroimaging studies investigating the neural substrates of attentional control. These studies have implicated the anterior cingulate (AC) as a mediator in conflict monitoring/control both before and after a response. Despite the wide-spread use of the flanker task in cognitive neuroscience, recent studies have used more detailed analyses of response time distributions to address attentional control. In particular, the use of distributional plots is becoming a preferred choice of analysis in recent years and has been employed in studies on ADHD. Here the question is addressed whether this type of analysis truly provides an estimation of cognitive control (seen by a change in slope of the function) as defined in computational models. Going beyond the mathematical critiques regarding the interpretation of actual values in distributional plots, results from a number of computational models of the Eriksen flanker task was subjected to detailed RT-analysis. A model without AC-control produced data that would be suggestive of cognitive control. A model with AC-control produced different results depending on the level at which control is exerted (response level, identity level, spatial crowding). The models are compared with results from an experiment that separate stimulus-stimulus from response-conflict. Implications for the use of distributional analysis and the general architecture for the flanker-model are discussed.

"*Conditional hazard functions for the analysis of cognitive models*"
Ami Eidels*, James Townsend, & Kan Torii
Indiana University
Response times (RT) are used by psychologists to infer about how we process information. Most RT distributions tend to be similar to each other, being unimodal and positively skewed, so it is difficult to tell what kind of statistical distribution they obey. However, some probability distributions with similar probability density and cumulative distribution functions can have different hazard functions, making the latter useful in distinguishing between models and understanding the characteristics of the mental process under investigation. In cognitive psychology, the hazard function of reaction time tells us the probability that processing will terminate in the next instant of time, given that it has not yet finished. In the current study we derived and simulated hazard functions of different processing models (namely, the two-state varied model, three types of diffusion models, the

race model) and showed that they may predict different shapes of the hazard function. We proposed (and simulated) an even more fine-grained analysis by introducing the conditional hazard functions: analyzing the hazard functions separately for correct and incorrect responses. Finally, we collected data from a simple two alternative forced choice task and compared the estimated hazard functions, standard and conditional, to those predicted by the different models. To obtain a reliable estimate, each participant performed in about 15,000 trials, under both high and low accuracy conditions. Accuracy manipulation allowed to collect enough observations for the incorrect analysis, as well as to compare performance (i.e., hazard function shape) between threshold and supra threshold conditions.

"*A Study of the State-Context Model of Concepts*"
Liane Gabora
University of British Columbia, Okanagan
When one conceives of a concept it is conceived in a particular context, and the context unavoidably colours how it is conceived. The State-COntext-Property (SCOP) theory of concepts was designed to model this effect of context (Aerts & Gabora 2005a, b; Gabora & Aerts 2002). A SCOP model of a concept consists of sets of (1) states, (2) contexts, (3) properties, (4) weights (applicability values) of properties for a given state, and (5) transition probabilities associated with a change from one state to another under a given context. Context has been shown to affect the applicability of properties and the typicality of exemplars (e.g., Barsalou 1982), an effect that is accounted for by other theories of concepts. The notion of 'state of a concept' in SCOP leads to the subtly more complex prediction that the applicability of each property varies for each context-driven transition from one particular state to another, as does the typicality of each exemplar. We present results that unequivocably support these predictions. Thus for example when asked to give a property of the concept 'hat' given the context 'worn at a rodeo', many subjects respond wide brim, but a small percentage respond pointy. Similarly, when asked for an exemplar of 'hat' given this context, most subjects respond cowboy hat, but a small percentage respond ball cap. This supports the notion of state and context-specific transition probabilities.

"*A Hidden Markov Model of Lexicon and Word Order Effects on Role Assignment*"
Shahram Ghiasinejad* & Richard Golden
University of Texas at Dallas
We review a computational model called AUTOCODER for coding free response data automatically and its performance on automatic semantic annotation of free response data. AUTOCODER system works by actively interacting with an experienced human coder who semantically annotates key words with "word-concepts" and sequences of word-concepts with "propositions". After training AUTOCODER on a set of 70 segmented and semantically annotated free response data originally generated by second and fifth graders, AUTOCODER exhibited a good proposition agreement rate of 91% and a good kappa agreement score of 65% with respect to an experienced human coder on an additional set of 24 unsegmented free response data. We illustrate AUTOCODER's use of knowledge of "word order" and "word identity" through a simulation study of the model operating in some simplified statistical environments. AUTOCODER was trained on the symmetric sentence "the man visited the woman" and tested on different variations of the same sentence in the task of agent role assignment. Results indicated that presence of word order information improved the systems performance in assigning agent roles and that this performance may be biased by changing the frequency of the exposure to certain word orders. We examined the same effects using an experimental paradigm. Twenty participants were asked to assign the agent role in symmetric content word sentences. Results indicated that people rely heavily on word order cues when assigning agent roles. Similar effect of bias was observed when people were biased against their natural tendencies in assigning agent roles. and size of selected KDC analyses using the simulation methodology are reported as well.

"*Simulation Studies of Statistical Inference in KDC Analysis*"
Perwaiz Ismaili
University of Texas at Dallas
The analysis of sequential categorical data arises in the context of many areas of psychology but such analyses tend to be limited because increasing the "Markov order" of the time-series or the number of categories results in a dramatic increase in the number of free parameters. Knowledge Digraph Contribution (KDC) analysis, an extension of multinomial logistic regression which encourages the incorporation of prior knowledge regarding the dynamics of the categorical time-series directly into the probability model. Specifically, such prior knowledge is represented in the form of a digraph which qualitatively specifies the likelihood one category follows another in the data. Different digraphs proposed by the theorist correspond to distinct model parameters. In this study, student responses to questions were modeled as time-series of integers where a particular integer corresponds to a particular proposition. The data was obtained in the multi-school ARCADE (Automated Reading Comprehension Assessment and Diagnostic Evaluation) project involving participants from San Diego and Chicago. The data was then used in conjunction with KDC analysis to examine the relative influence of different semantic structures guiding the order and content of student production data. Finally, the effectiveness of selected large-sample inferential statistics associated with KDC in this particular task were evaluated using a simulation study methodology. Standard errors of the parameter estimates computed from analytic formulas in KDC analysis will be compared with standard errors obtained from simulation methods. In addition, the power and size of selected KDC analyses using the simulation methodology are reported as well.

"*On the Cost and Benefit of Taking it out of Context: Modeling the Inhibition Associated with Directed Forgetting*"

Melissa Lehman*, Kenneth Malmberg, & Lili Sahakyan
University of South Florida, University of Noth Carolina

Forgetting can occur as the result of unconscious or automatic memory processes or as the result of conscious control. The latter form of forgetting is often referred to as suppression, repression, or inhibition, and it is investigated in the laboratory using the directed forgetting procedure. In the directed forgetting procedure, subjects are given material to memorize and some are instructed to forget part of the material after learning it. When tested on the "to be forgotten" material, subjects recall less than those who were not given instructions to forget some of the material. Additionally subjects who were instructed to forget some of the material remember more of the "to be remembered" material than subjects who were not given the forget instructions. The authors describe and empirically test the first formal model of directed forgetting, implemented within the framework of the Search of Association Memory Theory (SAM). The critical assumption is that episodic memory can be suppressed by a conscious attempt to alter the mental context in which new memories are encoded. The present model accounts for both veridical and erroneous free recall performance.

"*Nonlinear Dynamics of Stress, Coping and Related Variables*"

Lawrence Levy* & Richard W. J. Neufeld
University of Western Ontario

A behaviorally principled six-dimensional nonlinear dynamical-systems (NLDS) model of coping-related cognitive efficiency, cognition-intensive coping ("decisional control"), stress (Physical danger/discomfort; social evaluation) and collateral variables is described. The model consists of behaviorally-principled highly-coupled differential equations expressing continuous interactions among the system dimensions over time. Application of NLDS staples, notably identification and analysis of stable and unstable fixed points, and recent innovations for identifying chaotic regimes (extensions to Nicolis-Prigogine competitive-modes theory), disclose exotic mathematical properties that nevertheless are substantively significant. Despite its fundamentally behavioral moorings, the model is show to be capable of manifesting all the principle NLDS attractors; point equilibria; limit cycles and chaotic motion. Each simulates complex but potentially illuminating relations between psychological stress and cognition-dependent coping, and each is shown to be empirically addressable, along with being simulationally tractable.

"*An EEG study of landmark recognition during virtual navigation*"

Matt Mollison*, Josh Jacobs, Igor Korolev, & Michael Kahana
University of Pennsylvania

Computer-generated, three-dimensional environments were used to study implicit landmark recognition by having participants take on the role of a taxi driver. During the task, electrical activity on the scalp was measured at 128 locations, and behavioral data on actions within the environment were recorded. Event-related potentials (ERPs) were calculated for a time period surrounding the appearance of target and non-target locations on the computer screen, showing the cortical activation during the implicit recognition of these landmarks. Statistical tests reveal that scalp-recorded stimulus-locked voltage fluctuations are significantly greater during the viewing of target as opposed to non-target locations, with a positive-going deflection in the ERP waveform beginning at approximately 300-400 ms showing strongly on the left parieto-occipital area of the scalp. This effect, called the P300, is seen throughout the related literature, and is associated with stimulus processing. These findings provide evidence for significant differences in neural activity between two related, but functionally different, conditions in a complex spatial navigation task.

"*A robustness measure for fitted parameters of loudness equations*"

Lance Nizami
Boys Town National Research Hospital

There is no generally accepted equation for loudness as a function of stimulus intensity. The various proposed loudness equations contain unknown parameters that are typically estimated using Maximum Likelihood Estimation (MLE). In MLE, the empirical loudness is obtained by substituting the stimulus intensity into the loudness equation and adding an error term. When the latter is Gaussian, with zero mean and constant variance, as empirically justified for the logarithm of loudness, then maximizing the likelihood corresponds to minimizing the sum-of-squares-of-residuals (SSR). The "best" of the various loudness equations is considered that which maintains a realistic fit as judged by visual inspection, while having the most favorable combination of the fewest parameters and lowest SSR. The latter can, however, produce parameters whose values change broadly with a proportionately small change in SSR. Such parameter values are not credible. Sensitivity of SSR to change in parameter value is thus an objective measure of parameter robustness. The SSR for a function having 2 or more parameters forms a surface or hypersurface as a function of the parameters. Parameter robustness is not given by the rate-of-change of the SSR with respect to the parameter (because that rate approaches zero as the minimal SSR is approached), but rather by the curvature of the SSR surface with respect to the parameter, as rigorously defined from differential geometry. Examples will be given of the robustness of fitted parameters for various loudness equations.

"*Age differences in transitive associations*"

Jennifer Provyn*, S. V. Iyer, M. S. Sliwinski, &

Marc Howard
Syracuse University
Transitive associations are associations made among items that do not co-occur in time but that are presented in similar temporal contexts. For instance in a double function list of paired-associates that includes the pairs A-B and B-C, A and C become associated to each other, presumably because both were presented in the context of B. Younger and older participants learned single-function lists of paired associates with no contextual overlap (e.g., J-K, L-M) and double-function lists of paired-associated consisting of chains of pairs (e.g., A-B, B-C). Young adults out-performed old adults on both pair types. To look for age differences in transitive associations, we compared the intrusions made to single- and double-function probes. Despite their better overall performance, young adults were more susceptible to associative intrusions to double-function probes after intrusion levels were normalized, suggesting that transitive associations are sensitive to aging. The results are discussed in the context of the temporal context model and the hypothesis that older adults are impaired at forming new item-to-context associations.

"*Mann Whitney U test on reaction time simulations*"
Gregory Reaume* & John Miyamoto
University of Washington
Using simulations of data, we investigated the power and accuracy at nominal significance levels of a generalized Mann Whitney U test over different types of distributions. The classes of distributions examined were the normal and ex-Wald, as well as outlier contaminated data. We also show that this method can effectively be used to analyze reaction time using using actual data from a measure of reaction time, the Implicit Association Test.

"*The information mechanics of cognition: Quantum indeterminacy and probabilistic relativity in the field of verbal behavior*"
Ronald Saleh
New York City Department of Education
The purpose of the proposed research program is to develop and support a quantum-relativity probability calculus of verbal behavior following Lewin's classical field theory, e.g., B = f(P, E). This introduction to Information Mechanics (IM) presents a dynamical approach to relative frequency probabilities including (1) uncertainty relations for specifying the indeterminate nature of associate words in terms of non-commutative observables (e.g., informational position and momentum) and (2) relativistic factors for dynamically framing associate words as bits of information in motion in an interactive, interpersonal field. For example, it is hypothesized that relativistic transformations of measured data will absorb significant additional structural variations in both the subject's response time and the tester's switching pause time not accounted for by competing linear process models. Preliminary research appears to support these hypotheses. Moreover, the ultimate goal is to extend the basic principles and laws of IM, founded at the level of word information, to the level of message information and general discourse. Research is needed to potentially establish IM as a scientific paradigm for psychology and its many related fields, such as artificial intelligence. This program should begin with the development of a fully interactive and adaptive computerized word association test with IM-based algorithms for simulating the natural rhythms and regulations of an ideal type of human test administrator.

"*Electrophysiological correlates of serial position and memory performance in free recall*"
Per Sederberg, Julia Barnathan*, Jonathan Miller, & Michael Kahana
University of Pennsylvania
Although there are many well-characterized behavioral effects seen in free recall, there is little work that relates the behavioral dynamics to the underlying brain electrophysiology. For example, both temporal (Kahana 1996) and semantic (Howard & Kahana, 2002) associations affect output order at retrieval, but the brain activity while these two types of associations are being formed is unknown. We recorded scalp EEG as participants studied lists of common words with varying semantic similarity and then performed a delayed free-recall task. We categorized recall transitions based on varying degrees of semantic similarity and temporal proximity in the analogous presented list. A positive deflection in the frontal ERP is seen when forming an association between nearby as opposed to distant list items. This frontal deflection is greatest when the association is made to a nearby word that is semantically similar. When making associations between words that appeared far apart in the list, posterior ERPs are greater when these words are semantically similar. These results indicate that frontal and posterior brain areas contribute differently when forming semantic and temporal associations.

"*Perceptual decisions under risk in extrapolating curved motion paths*"
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Although traditional work on decision making has demonstrated systematic deviations from optimality, recent experiments on movement planning show that subjects can be near optimal in their visuo-motor decisions (Trommershaeuser et al., SpatialVision2003). We extend a paradigm recently used to study the visual extrapolation of contour geometry (Singh & Fulvio, PNAS2005), to examine observers' decisions under risk, in visually extrapolating curved motion paths behind an occluder. Methods: Observers viewed a dot moving along a parabolic path disappear behind the straight-edge of a half-disk occluder. Their task was to "catch" the dot from the opposite, curved side by adjusting the angular position of a curved "mit" (length = 20 degrees). In the risk conditions, a double-mit was used, compris-

ing a reward zone and a penalty zone, with overlap. Observers' earnings/losses were determined by the part of the double-mit that "caught" the dot. Variables manipulated were: path curvature (0.1185, 0,237 deg^{-1}), penalty value (-200, -500), and degree of overlap between the mits (-0.5, -0.25, +0.25, +0.5). Results: Observers' performance in the baseline condition was used to estimate individual bias and variability. Based on these, predictions of optimal shift from baseline and optimal score were computed for each risk condition. The observed shifts were strongly predicted by the optimal shifts (R^2s between 0.88 and 0.94). Moreover, observer efficiency (obtained/optimal score) was high, ranging between 80% and 99% across observers. The results indicate that the observers make near optimal perceptual decisions, taking into account their inherent variability, in extrapolating curved motion paths under risk.

"*Simple learning models can illuminate biased results from titration experiments*"

Abran Steele-Feldman* & James Anderson
University of Washington

Many discrete trials operant conditioning experiments utilize a titration procedure (Mazur, 1984) which presents a repeated choice between a standard alternative providing a stationary reward schedule and an adjusting alternative for which the reward schedule is adjusted based on the subject's previous choices. The procedure is designed to determine the point of indifference between the two schedules and several studies have demonstrated a titration bias: indifference is obtained with an adjusting reward that is significantly larger than the reward provided by the standard option. Analyzing Bateson & Kacelnik's (1995), titration experiment on starlings as a Markov birth death process, we show how a class of simple learning models using ratio-based choice functions will invariably produce a titration bias. The analysis suggests that the choice between the standard and adjusting schedules was based on the rewards ratio, not their difference, and therefore sheds light on the choice function debate (e.g., Fantino & Goldshmidt 2000). More importantly the analysis shows that simple learning models cannot quantitatively fit all the data from this experiment and explains this failure in terms of differences in responses to transient and stationary reward distributions. Finally, these results highlight the need to examine model predictions in quantitative detail before drawing inferences about experimental results.

"*Reconciling single-process and two-process accounts of item recognition*"

Yaofei Zhang* & Marc Howard
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After decades of study, the question of whether recognition memory relies on one continuous process or two discrete processes remains hotly debated. Recent evidence from studies of item recognition that used travel pictures as stimuli have shown that the Yonelinas high threshold (YHT) model, a formal implementation of two-process theory, provides a superior fit relative to the normal unequal variance (NUV) model, a formal implementation of single-process theory. This finding contradicts a wealth of evidence from the study of item recognition using words as stimuli. We attempted to reconcile these findings by conducting an item recognition experiment in which type of study material was a between-subjects variable. We replicated earlier findings of a superior fit for the YHT to item recognition with picture stimuli. However, we also observed an interaction of model and material type, such that the NUV provided a better fit to item recognition of words. On its face, this seems to imply that item recognition relies on a single process if the materials are words, but two processes if the study materials are pictures—a rather unsatisfactory conclusion. The results are discussed in light of the variable recollection model, a some-or-none two-process account that includes the YHT and NUV as special cases.