CURRENT TRENDS IN MATHEMATICAL PSYCHOLOGY

A symposium organized by the Society for Mathematical Psychology

Hosts: Clintin Davis-Stober, Pernille Hemmer

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Strand 10A, 2nd Floor

The Society for Mathematical Psychology promotes the advancement and communication of research in mathematical psychology and related disciplines. Mathematical psychology is broadly defined to include work of a theoretical character that uses mathematical methods, formal logic, or computer simulation.

SYMPOSIUM SCHEDULE

9:00	*Opening remarks*	
Session I: Perception and Memory		
9:05	Qiong Zhang (CMU)	A rational account of exploration-exploitation in human memory search
9:25	Jeff Zemla	Comparison of semantic networks in Alzheimer's patients and controls
9:45	Jeremy Caplan	Model mechanisms of the congruity effect from comparative judgements to one-trial episodic memory
10:05	*Break until 10:35*	
Session II: Decision Making Session I		
10:35	Joyce Zhao	A taxonomy of behavioral interventions
10:55	Lael Schooler	Cognitive costs of decision-making strategies: A resource demand decomposition analysis with a cognitive architecture
11:15	*Lunch until 13:00*	
13:00	*Poster session until 14:15*	
Session III: Decision Making Session II		
14:15	Randy Jamieson	An instance theory of semantic memory
14:35	David Budescu	Estimating subjective probability distributions to reduce elicitation biases
14:55	Claudia González-Vallejo	Examining aspects of decision difficulty with dynamic, pre-decisional measures in various contexts: consumer, gamble, and intertemporal choices.
15:15	Adele Diederich & Scott Brown	Updates from Journal of Mathematical Psychology and Computation, Brain & Behavior

ABSTRACTS

Session I:

A rational account of exploration-exploitation in human memory search
Qiong Zhang, Carnegie Mellon University

A central paradigm to study human memory search is the semantic fluency task, where participants are asked to retrieve as many items as possible from a category in a fixed amount of time. Observed responses tend to be clustered semantically. To understand when the mind decides to stop exploiting the current patch and to start exploring the next, recent work has proposed two competing mechanisms. Under the first mechanism, people make the strategic decision to switch away from a depleted patch based on the marginal value theorem, similar to optimal foraging in a spatial environment. The second mechanism demonstrates that similar behavior patterns can emerge in a random walk on a semantic network, without necessarily involving strategic switches. In the current work, instead of comparing existing mechanisms over observed human data, we propose a rational analysis of the problem by examining what would be an optimal patch-switching policy under the framework of reinforcement learning. Built upon the random walk model and based on features of the local semantic patch, the reinforcement learning agent gives rise to a third switching mechanism that performs the task better than existing mechanisms. This result sheds light on how policies derived from an optimal AI agent can be adopted as a hypothesis about human cognitive mechanisms in the same task.

Comparison of semantic networks in Alzheimer's patients and controls
Jeff Zemla, University of Wisconsin-Madison

The semantic fluency task (freelisting of items from a category) is regularly used in clinical settings to assess individuals with memory impairments such Alzheimer's Disease (AD). Though the task is diagnostically useful, the cognitive mechanisms that lead to impairments on the task are unclear. Central to this debate is whether these deficits are chiefly due to degradation of an individual's semantic representation or failures in executive functioning. We extend a generative model of healthy semantic fluency production to account for impairments due to AD. Additionally, we invert this model to estimate semantic network representations of individuals with and without AD. We find several differences in semantic networks between groups that may explain impairment on the task.

Model mechanisms of the congruity effect from comparative judgements to one-trial episodic memory
Jeremy B. Caplan and Yang S. Liu; University of Alberta

In episodic memory tasks, participants are faster and more accurate at judging which of two probe items came earlier when items are from early in the list, but which item came later when items are from late in the list. Although this came out of left field in episodic memory research (where the paradigm is prejudicially called judgements of recency), is extremely common, highly replicated, in comparative-judgement research. Comparative-judgement researchers have narrowed in on quantitative model accounts of the congruity effect. However, we are discovering that for paradigms derived from episodic memory research, previously rejected mechanisms might, in fact, be favoured. This cross-disciplinary perspective suggests more diversity of causes of congruity effects, despite their superficial resemblance. This expands the repertoire of model mechanisms, each with particular boundary conditions.

A taxonomy of behavioral interventions
Joyce Zhao & Sudeep Bhatia; University of Pennsylvania

Choice behavior can be influenced by many different types of incidental contextual factors, including those pertaining to presentation format, emotion, social belief, and cognitive capacity. Many of these contextual factors form the basis of behavioral interventions, or "nudges", used by academics and practitioners to shape choice. In this paper we propose an empirical taxonomy of seventeen different behavioral interventions, based on data from a large-scale choice experiment. Our taxonomy analyzes these interventions using the drift diffusion model (DDM), a quantitative theory of decision making whose parameters offer a theoretically compelling characterization of the neurocognitive and statistical underpinnings of choice behavior. By studying a large number of behavioral interventions through the lens of the DDM, we are able to precisely measure, quantify, and compare the effects of these interventions, and interpret these effects in terms of their descriptive, mechanistic, and normative implications.

Cognitive costs of decision-making strategies: A resource demand decomposition analysis with a cognitive architecture
Hanna B. Fechner, **Lael J. Schooler**, & Thorsten Pachur; University of Basel, Syracuse University, & Max Planck Institute for Human Development

To measure the effort—or cognitive costs—associated with a decision strategy we developed a method we call Resource Demand Decomposition Analysis (RDDA). RDDA attributes the effort required by a strategy to the demands it places on specific cognitive resources. We instantiate RDDA and simulate strategies in the ACT-R cognitive architecture. Using RDDA, we compared the cognitive costs of two prominent decision strategies, take-the-best (TTB) and tallying. Because TTB may ignore information and forego information integration, it has been said to entail lower cognitive costs than strategies like tallying. However, simulations and a behavioral study demonstrate that under increasing cognitive demands the response times of TTB can exceed those of tallying. RDDA suggests TTB requires more working memory updates and memory retrievals than tallying. The results illustrate the benefits of assessing the cognitive costs of a strategy by understanding how it is embedded in the cognitive system.

Session II:

An instance theory of semantic memory
Randall K. Jamieson, University of Manitoba, Johnathan E. Avery (Indiana), Brendan T. Johns (SUNY Buffalo) & Michael N. Jones (Indiana)

Distributional semantic models (DSMs) specify learning mechanisms with which humans construct a deep representation of word meaning from statistical regularities in language. Despite their remarkable success at fitting human semantic data, virtually all DSMs may be classified as prototype models in that they try to construct a single representation for a word's meaning aggregated across contexts. This prototype representation conflates multiple meanings and senses of words into a center of tendency, often losing the subordinate senses of a word in favor of more frequent ones. We present an alternative instance-based DSM based on the classic MINERVA 2 multiple-trace model of episodic memory. The model stores a representation of each language instance in a corpus, and a word's meaning is constructed on-the-fly when presented with a retrieval cue. Across two experiments with homonyms in both an artificial and natural language corpus, we show how the instance-based model can naturally account for the subordinate meanings of words in appropriate context due to nonlinear activation over stored instances, but classic prototype DSMs cannot. The instance-based account suggests that meaning may not be something that is created during learning or stored per se, but may rather be an artifact of retrieval from an episodic memory store.

Estimating subjective probability distributions to reduce elicitation biases.
David V Budescu, Yuyu Fan & Emily Ho; Fordham University

Subjective probabilities play a major role in many aspects of JDM research, as well as in numerous decision analyses applications. The various methods used to elicit probabilities are notoriously susceptible to multiple cognitive biases. We propose a new methodology for *estimating* subjective probability distributions of continuous variables that can reduce many of these biases. In our methodology – labeled Ratio Judgment and Scaling (RJS) – judges are asked to compare all pairs of possible outcomes and identify in each case which of the two is more likely, and by how much. These comparative judgments generate a matrix of ratio judgments from which one can estimate the target probability distributions by standard statistical methods. We describe
(1) a simulation study to identify optimal ways of binning a continuous distribution for the purpose of applications of the methodology;
(2) experimental studies contrasting the new RJS method with standard elicitation methods for various partitions of random continuous variables; and
(3) field studies using the RJS method with experienced climate scientists making judgments in their domain of expertise.
The results provide empirical support for the feasibility and validity of the new method and demonstrate its superiority over standard methods, suggesting that the RJS methodology is a viable candidate for replacing standard elicitation methods.

Examining aspects of decision difficulty with dynamic, pre-decisional measures in various contexts: consumer, gamble, and intertemporal choices.
Claudia González-Vallejo & Jiuqing Cheng; University of Ohio

The study examined the two-factor structure of decision difficulty proposed by Cheng and González-Vallejo (2017) in several domains. Using the measurement methodology of 'mouse' (cursor) movements, participants' temporal and spatial measures were recorded when making decisions in inter-temporal, gamble, and consumer choices. Task manipulations designed to affect difficulty included the sign of the payoffs (gains vs. losses), the similarity of the attribute values being compared, and attribute importance. A psychometric analysis of the measures revealed three orthogonal components, two of which, conflict and wavering, described decision difficulty. The conflict component was most affected by changes in the sign of the payoffs of inter-temporal and gamble choices, with greater means observed in the loss than in the gain context. By contrast, the wavering component was most affected by changes of the similarity between the options' attributes, with greater means when the options were more similar.