MathPsych/ICCM 2024

Tilburg University

Welcome

Dear Colleagues,

I am delighted to welcome you to the 57th Annual Meeting of the Society for Mathematical Psychology (MathPsych) and the 22nd International Conference on Cognitive Modeling (ICCM) at Tilburg University, the Netherlands. Our joint format ensures that all sessions are open to all attendees, encouraging enriching cross-disciplinary dialogue.

When asked about my favorite conference, I always say it's MathPsych/ICCM. Each session I attend brings new insights, innovative methods, and the opportunity to connect with colleagues. Moreover, every time I share my work, I gain new perspectives that enhance my research. I anticipate this year's meeting will be equally rewarding for all of us.

Our program committee has curated an engaging schedule. I urge everyone to attend the keynote addresses by Professor Iris van Rooij and Professor Iris Groen. On the first day, we will host a Senior Fellow fireside chat with 2023 winner Professor Rich Shiffrin, moderated by Professor EJ Wagenmakers. This marks the first time we're able to conduct this event live. Additionally, later in the conference, we'll hear from the William K. Estes Early Career Award 2023 winner, Professor Gregory Cox. These sessions promise to be highlights of the conference. The 2024 awards including the William K. Estes Early Career Award, R. Duncan Luce Outstanding Paper Award, Computational Brain & Behavior Outstanding Paper Award, and the Society for Mathematical Psychology Senior Fellow Award will be announced at our virtual business meeting on 21 July, 2024.

Please join me in expressing gratitude to this year's conference organizers. Our local team, chaired by Bruno Nicenboim and supported by Noortje Venhuizen and Drew Hendrickson, alongside ICCM representatives Catherine Gilbert, Marco Ragni, and Jelmer Boast, and the Society's representatives Joachim Vandekerckhove, Leslie Blaha, Betsy Fox, and Peter Kvam, have worked tirelessly to bring this meeting to fruition. If you encounter them, please take a moment to thank them for their dedication and effort.

I look forward to seeing you this year.

Sincerely,

Timothy J. Pleskac
President of the Society for Mathematical Psychology

mathpsych.org

About MathPsych/ICCM 2024

MathPsych

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. The official journals of the society are the *Journal of Mathematical Psychology* and *Computational Brain & Behavior*.

ICCM

The International Conference on Cognitive Modeling (ICCM) is the premier conference for research on computational models and computation-based theories of human behavior. ICCM is a forum for presenting, discussing, and evaluating the complete spectrum of cognitive modeling approaches, including connectionism, symbolic modeling, dynamical systems, Bayesian modeling, and cognitive architectures. ICCM includes basic and applied research, across a wide variety of domains, ranging from low-level perception and attention to higher-level problem-solving and learning.

Contents

Code of conduct

The Society for Mathematical Psychology (SMP) is committed to the highest standards of diversity, equity, inclusion, and the free expression of ideas. We seek to provide an environment in which diverse participants may learn, network, and enjoy the company of colleagues. We recognize a shared responsibility to create and sustain that environment for the benefit of all. This Code of Conduct sets forth our commitment to providing a harassment-free and inclusive environment at SMP sponsored events (including all scientific meetings) as well as for all individuals engaged in SMP related business. All forms of harassment are prohibited. Specific prohibited behaviors include but are not limited to the following:

- Harassment or intimidation based on gender, gender identity, gender expression, age, sexual orientation, disability, appearance, body size, race, ethnicity, political orientation and views, religion (or lack thereof), or other group status
- Unwelcome behavior as well as verbal or written comments (including online comments) related to the above categories that create a hostile meeting environment (e.g., sexist or racist jokes)
- Sexual harassment or intimidation, including unwelcome sexual attention
- Unwelcome physical contact
- Harassing photography or recording
- Stalking or following (physical or virtual)
- Sustained disruption or threatening of conference presenters
- Cyberbullying (i.e., the use of computers, cell phones or other devices to send or post emails, text messages or images intended to harass another person) and social media abuse
- Advocating for, or encouraging, any of the above behavior
- This code of conduct is not intended to limit the terms of open and respectful scientific inquiry or discussion. Critical examination, debate, and robust disagreement regarding beliefs and viewpoints, germane to the topic of discussion and presented respectfully do not, in themselves, constitute harassment.

We expect individuals to follow this code of conduct at all SMP scientific meetings and in all other SMP related business.

Enforcement

Individuals asked to stop any harassing behavior are expected to comply immediately. If an individual engages in harassing behavior, the SMP executive board retains the right to take any actions to keep SMP a welcoming

environment for all individuals. These actions include simply warning the offender, expulsion from a scientific meeting with no refund of registration or other attendance-related costs, expulsion from the society, and/or banishment from all future SMP meetings. Appeals for any of these actions will be handled by the executive board.

Reporting

If you are being harassed, notice that someone else is being harassed, or have any other concerns, please report it to us immediately. We value your involvement in SMP, and will make every effort to ensure that you feel safe and welcome in our society.

You can make a report by emailing info@mathpsych.org. This email is directly monitored by the secretary/treasurer and the president. Any reports made by email will be accessible by the executive board. You may also make a report in person to any member of the executive board.

Workshops and social events

SE: Social event, WS: Workshop

Workshops

Date	Session	
July 19 10:00 – 13:30	WS	Workshop: Reinforcement Learning Modeling For Human Choice Behavior (de Groot | CUBE 216 room)
July 19 10:00 – 13:30	WS	Workshop: How To Publish And Evaluate Your Model (Révész | CUBE 217 room)
July 19 15:00 – 18:30	WS	Workshop: Women of Mathematical Psychology - Professional Representation for Inclusivity and Minority Empowerment (WOMP-PRIME) Professional Development Symposium (Auditorium | CUBE 1 room)
July 23 10:00 – 18:00	WS	Workshop: ACT-R (Vuyk | CUBE 220 room)

Social events

All the social events will be held on the Open Space of the Cube building.

Date	Session	
July 19 18:30 – 20:00	SE	Opening Reception
July 20 17:00 – 20:00	SE	MathPsych Posters
July 20 17:00 – 20:00	SE	ICCM Posters
July 20 17:00 – 20:00	SE	Funding opportunities at the NSF
July 21 18:30 – ?	SE	Conference dinner at the Restaurant Auberge d' Bonheur

MathPsych/ICCM Schedule | July 20

CT: Contributed Talk, KN: Keynote, SY: Symposium

9:00 - 17:00 | Registration

CUBE 36	**9:00-10:00 | CBB Editioral board meeting**

Room		**10:00-11:40 | Symposium: Advancing Dynamic Models of Psychological Processes**	
de Groot CUBE 216	SY	**Snijder, A.**	A multiverse analysis of the psychometric properties and robustness of dynamic structural equation models
de Groot CUBE 216	SY	**Aristodemou, B.**	You Could do Better Tomorrow - Modeling day to day fluctuations in cognitive performance
de Groot CUBE 216	SY	**Berkhout, J.**	Theoretical implications of how we model night gaps in ESM
de Groot CUBE 216	SY	**Kievit, R.**	Capturing asymmetrical temporal dynamics using thresholded time series models
de Groot CUBE 216	SY	**Schaaf, M.**	A state-based time series model capturing mood fluctuations over time

Room		**10:00-11:40 | Memory**	
Révész CUBE 217	CT	**Huang, J.**	How cognitive load and cognitive reflection impact probability judgments?
Révész CUBE 217	CT	**Haridi, F.**	Semantic Similarity and Context Cues alleviate Set-size Effects on Long-Term Memory Retrieval Times
Révész CUBE 217	CT	**Potthoff, C.**	Working memory, attention and executive control in digit span tasks
Révész CUBE 217	CT	**Göttmann, A.**	Neurocognitive psychometrics of interindividual differences in working memory
Révész CUBE 217	CT	**Shiffrin, R.**	The REM model of Shiffrin & Steyvers (1997) Predicts 2AFC and Four-way Classification (4WC)

Room	**10:00-11:40 | Risky choice 1**

Donders CUBE 218	CT	**Hof, L.**	How sampling strategies shape risky choice
Donders CUBE 218	CT	**Lob, A.**	Modeling the roles of epistemic and aleatory uncertainty in people's subjective perceptions of uncertainty
Donders CUBE 218	CT	**Li, Y.**	The influence of probability versus utility on repeated mental simulations of risky events
Donders CUBE 218	CT	**Maier, M.**	Investigating Risky Choices With 'Fatal' Outcomes Using the Extinction Gambling Task
Donders CUBE 218	CT	**Pachur, T.**	An affect-based computational framework for modeling risky choice with nonmonetary outcomes

Room	10:00-11:40 | **Evidence accumulation: Race Models**		
Mellenbergh CUBE 219	CT	**Alauki, A.**	Evaluating the effects of response scale resolution on confidence judgements: A Multiple Threshold Race model approach
Mellenbergh CUBE 219	CT	**Jahansa, P.**	Modeling the stop signal task: further results on the copula approach
Mellenbergh CUBE 219	CT	**Ebrahimi Mehr, M.**	Examining the Psychological Significance of the Jumps in the Decision Process through Test-Retest Reliability Analysis
Mellenbergh CUBE 219	CT	**Voss, A.**	Is Evidence Accumulation Jumpy? A Lévy-Flight Model explains Fast Errors in Perceptual Decision Making
Mellenbergh CUBE 219	CT	**Hato, T.**	Bias Against Lévy Flight: What Happens When We Misspecify Lévy Flight as Diffusion Model?

Room	10:00-11:40 | **ICCM: Linguistic Phenomena**		
Vuyk CUBE 220	CT	**van de Braak, L.**	Intractability obstacles to explanations of communication
Vuyk CUBE 220	CT	**Woensdregt, M.**	Challenges for a Computational Explanation of Flexible Linguistic Inference

Vuyk CUBE 220	CT	**Matsumuro, M.**	Memory activation and retrieval strategy in lexical alignment: Comparing the ACT-R model of human and computer interlocutors
Vuyk CUBE 220	CT	**Nishikawa, J.**	Exploring an Approach for Phonological Awareness Estimation Employing Personalized Cognitive Models and Audio Filters
Vuyk CUBE 220		**Group Q & A**	

11:40-12:00 | Coffee break

12:00-13:00 | Keynote speaker: Iris Groen - ICCM			
Auditorium CUBE 1	KN	**Groen, Iris**	Modelling real-world visual perception with deep learning

13:00-14:00 | Lunch break, JMP Board Meeting (CUBE 36)

Room	**14:00-15:40 | Language & AI**		
de Groot CUBE 216	CT	**Ostrovsky, T.**	From Verbal Reports to Model Validation: Theoretical Framework and Application
de Groot CUBE 216	CT	**Ungermann, P.**	Using LLMs to automate the analysis of verbal report
de Groot CUBE 216	CT	**Ye, Y.**	Conceptions of status: A natural language processing approach
de Groot CUBE 216	CT	**Cornell, C.**	The Role of Episodic Memory in Storytelling: Comparing Large Language Models with Humans
de Groot CUBE 216	CT		Withdrawn

Room	**14:00-15:40 | Statistics**		
Révész CUBE 217	CT	**Steinhilber, M.**	The Dark Side of Sequential Testing: A Simulation Study on Questionable Research Practices

de Groot CUBE 216	CT	**Failenschmid, J.**	Exploring non-linear trajectories in intensive longitudinal data: A comprehensive review of the available statistical methods
de Groot CUBE 216	CT	**Stevenson, N.**	Generalized Bayesian hierarchical structural equation modeling
de Groot CUBE 216	CT	**Donzallaz, M.**	Spurious correlations in cognitive models: Bayesian hierarchical modeling to the rescue
de Groot CUBE 216	CT	**Aktepe, S.**	Assessing the relevance of random effects for statements in mixed-effects models of the illusory truth effect

Room	**14:00-15:40 | Mental architectures & information processing**		
Donders CUBE 218	CT	**Zhang, H.**	Deciphering Decision-Making Efficiency: The interplay of reliability and credibility in automated information processing
Donders CUBE 218	CT	**Liu, Y.**	Varieties of Selective Influence: Toward a More Complete Taxonomy and Implications for Systems Identification
Donders CUBE 218	CT	**Houpt, J.**	Deriving critical tests of ACT-R using systems factorial technology with global model analysis
Donders CUBE 218	CT	**Fific, M.**	MSPN: A Modular Serial-Parallel Network for Computational Modeling of Response Time and Choice in Facial Recognition Across Composite, Part-to-Whole, and Other-Race Effect Paradigms
Donders CUBE 218	CT	**Turner, B.**	Learning in the Context of Partial Information

Room	**14:00-15:40 | Evidence Accumulation: Multi-Attributes, Multi-Responses, and Complexity**		
Mellenbergh CUBE 219	CT	**Rieskamp, J.**	A computational framework to account for visual attention in multi-attribute decisions
Mellenbergh CUBE 219	CT	**Fernandez, K.**	Cognitive models of multi-response choice

Mellenbergh CUBE 219	CT	**Gonçalves, D.**	Speed, accuracy, and complexity
Mellenbergh CUBE 219	CT	**Mayaux, D.**	Value and contrast in evidence accumulation models
Mellenbergh CUBE 219	CT	**Nie, M.**	Analyzing the Impact of Choice Complexity on Risky Choices

Room		**14:00-15:40 | ICCM: Emotion & Cognition**	
Vuyk CUBE 220	CT	**Lebiere, C.**	A Proposal for Extending the Common Model of Cognition to Emotion
Vuyk CUBE 220	CT	**Nagashima, K.**	Trait Inference on Cognitive Model of Curiosity: Relationship between Perceived Intelligence and Levels of Processing
Vuyk CUBE 220	CT	**Conway-Smith, B.**	The Computational Mechanisms of Detached Mindfulness
Vuyk CUBE 220	CT	**Werk, A.**	How to Provide a Dynamic Cognitive Person Model of a Human Collaboration Partner to a Pepper Robot
Vuyk CUBE 220		**Group Q & A**	

15:40-16:00 \| Coffee break

16:00-17:00 | Fireside Chat: Rich Shiffrin			
Auditorium CUBE 1	KN	**Shiffrin, Rich**	Fireside Chat with Senior Fellow, Moderated by E.-J. Wagenmakers

17:00-20:00 \| Poster session (Funding opportunities at the NSF)

MathPsych/ICCM Schedule | July 21

CT: Contributed Talk, KN: Keynote, SY: Symposium

9:00 - 17:00 | Registration

9:00-10:00 | WoMP Advisory board meeting (CUBE 36)

Room		**10:00-11:00 | Symposium: Computational Psycholinguistics**	
de Groot CUBE 216	SY	**Paape, D.**	Using multinomial processing trees to model latent cognitive processes during garden-pathing
de Groot CUBE 216	SY	**Coco, M.**	Scan Pattern Similarity Predicts the Semantic Similarity of Sentences Across Languages Above and Beyond Their Syntactic Structure
de Groot CUBE 216	SY	**Bolliger, L.**	Introducing ScanDL: A diffusion-based generative model of eye movements in reading

Room		**10:00-11:00 | Evidence accumulation & neuroscience**	
Révész CUBE 217	CT	**Boag, R.**	A consensus guide to planning tasks for evidence accumulation modelling
Révész CUBE 217	CT		Withdrawn
Révész CUBE 217	CT	**Weindel, G.**	Hidden multivariate pattern analysis reveals the duration of encoding and decision processes in single-trial EEG data

Room		**10:00-11:20 | Real-world decisions**	
Donders CUBE 28	CT	**Mohammad, S.**	Modeling overtaking decisions in dynamic traffic interactions using generalized drift-diffusion models
Donders CUBE 28	CT	**Pleskac, T.**	Understanding Race Bias in the Decision to Shoot with an Integrated Model of Decision Making
Donders CUBE 28	CT	**von Krause, M.**	Exploring the associations of diffusion decision model parameters with socioeconomic success

Donders CUBE 28	CT	**Lo, C.**	To compete, or not to compete, that is the question

Room		**10:00-11:00 | Philosophy & theory**	
Mellenbergh CUBE 219	CT	**Szollosi, A.**	Invariants of human behaviour revisited: Snapshot vs universal explanations in psychology
Mellenbergh CUBE 219	CT	**Donkin, C.**	What makes formal modelling work?
Mellenbergh CUBE 219	CT	**Tabakci, C.**	Comparing Bayesian and non-Bayesian accounts of human confidence reports: A computational replication study

Room		**10:00-11:20 | ICCM: Problem Solving Skills**	
Vuyk CUBE 220	CT	**Williams, A.**	"I Knew it!" Model-Based Dissociation of Prior Knowledge Confounds in Memory Assessments"
Vuyk CUBE 220	CT	**Ragni, M.**	Predicting complex problem solving performance in the tailorshop scenario
Vuyk CUBE 220	CT	**Larue, O.**	Exploring Analogical Transfer with Tower of Hanoi Isomorphs
Vuyk CUBE 220	CT	**Ben-Artzi, I.**	Computational mechanisms underlying latent value updating of unchosen actions

11:20-11:40 | Coffee break

Room		**11:40-12:40 | Symposium: Computational Psycholinguistics**	
de Groot CUBE 216	SY	**Brouwer, H.**	Retrieval (N400) and Integration (P600) in language comprehension
de Groot CUBE 216	SY	**Frank, S.**	Neural language model gradient as a predictor of ERPs and sentence acceptability
de Groot CUBE 216	SY	**Rabovsky, M.**	Interindividual differences in predicting words versus sentence meaning: Explaining N400 amplitudes using large-scale neural network models

Room	**11:40-13:00 | Risky choice 2**

Révész CUBE 217	CT	**Marti, M.**	Decomposing financial decision-making with feedback
Révész CUBE 217	CT	**Regenwetter, M.**	Choose for others as you would choose for yourself? A layered analysis of probabilistic preferential choice
Révész CUBE 217	CT	**Olschewski, S.**	Risk Seeking and Risk Aversion in Choices and Valuations from Experience

Room		**11:40-12:40 | Real-world modeling**	
Donders CUBE 28	CT	**Schnuerch, M.**	Pinocchio disassembled: Hierarchical diffusion modeling of the cognitive cost of lying
Donders CUBE 28	CT	**Laskar, P.**	A Reciprocal-Practice-Success (RPS) model of free practice
Donders CUBE 28	CT		Withdrawn

Room		**11:40-13:00 | Reinforcement learning**	
Mellenbergh CUBE 219	CT	**Collingwood, C.**	A two-drift race model of human habits
Mellenbergh CUBE 219	CT	**Miletić, S.**	Understanding the structure of fluctuations in decision making
Mellenbergh CUBE 219	CT	**Danwitz, L.**	Framing the Exploration-Exploitation Trade-Off: Distinguishing Between Minimizing Losses and Maximizing Gains
Mellenbergh CUBE 219	CT	**Thalmann, M.**	How General Are Individual Differences in Exploration Strategies?

Room		**11:40-13:00 | ICCM: Reasoning patterns**	
Vuyk CUBE 220	CT	**Taylor-Davies, M.**	Rational Compression In Choice Prediction
Vuyk CUBE 220	CT	**Ragni, M.**	Predictive Algorithms for Individual Reasoning about Possibilities
Vuyk CUBE 220	CT	**Todorovikj, S.**	Model verification and preferred mental models in syllogistic reasoning

Vuyk CUBE 220		**Group Q & A**

13:00-14:00 | Lunch break

13:00-14:00 | SMP Executive Committee meeting (CUBE 36)

14:00-15:00 | Keynote speaker: Iris van Rooij			
Auditorium CUBE 1	KN	**van Rooij, Iris**	Reclaiming AI as a theoretical tool for cognitive science

15:00-15:20 | Coffee break

Room	**15:20-16:20 | Symposium: Computational Psycholinguistics**		
de Groot CUBE 216	SY	**Dotlacil, J.**	Studying language and cognition using models of discourse meanings
de Groot CUBE 216	SY	**Cassani, G.**	Meaning modulations and stability in Large Language Models: An analysis of BERT embeddings for psycholinguistic research
de Groot CUBE 216	SY	**Duff, J.**	Modeling individual differences in a pragmatic reference game as a consequence of variable disengagement from unsuccessful strategies

Room	**15:20-16:40 | Signal detection theory**		
Révész CUBE 217	CT	**Fischer, O.**	Two perspectives on decisions under risk and uncertainty: Modeling discrepancies and their psychological explanations
Révész CUBE 217	CT	**Jakob, M.**	An empirical test of the two-high-threshold contrast model
Révész CUBE 217	CT	**Biegler, R.**	Time-variant payoffs and signal detection theory
Révész CUBE 217	CT	**Koß, C.**	Reconciling signal-detection models of criterion learning with the generalized matching law

Room	15:20-16:40 | **Executive functions & cognitive control**		
Donders CUBE 28	CT	**Wientjes, S.**	Episodic retrieval of cognitive control demand: A computational model
Donders CUBE 28	CT	**Fradkin, I.**	How do we avoid doing or saying the wrong thing at the wrong time: exerting cognitive control during and after accumulation of internal evidence
Donders CUBE 28	CT	**Yim, H.**	Is focusing enough in category learning?
Donders CUBE 28	CT	**Heathcote, A.**	Choice models for the Dual-Modes of Cognitive Control task battery

Room	15:20-16:40 | **Reasoning**		
Mellenbergh CUBE 219	CT	**Zimmermann, K.**	Jumping to racial prejudice
Mellenbergh CUBE 219	CT	**Ilić, M.**	Testing AI models as cognitive models for abstract reasoning development
Mellenbergh CUBE 219	CT	**Cruz, N.**	Disentangling conditional dependencies
Mellenbergh CUBE 219	CT	**Himmelstein, M.**	Measuring Persuasion Without Measuring a Prior Belief: A New Application of Planned Missing Data Techniques

Room	15:20-16:40 | **Mental representation**		
Vuyk CUBE 220	CT	**Yan, H.**	Recovering individual mental representations of facial affect using Markov Chain Monte Carlo with People and Gatekeepers
Vuyk CUBE 220	CT	**Yu, K.**	Exploring latent processes of human generalization via computational modeling
Vuyk CUBE 220	CT	**Shahar, N.**	State-independent and outcome-irrelevant model-free learning

16:40-17:40 | SMP Business Meeting (Auditorium | CUBE 1)

18:30 | Conference dinner (Auberge du Bonheur, Bredaseweg 441, Tilburg)

CT: Contributed Talk, KN: Keynote, SY: Symposium

9:00 - 17:00 | Registration

Room	10:00-11:20 | Beliefs & selective attention		
de Groot CUBE 216	CT	**Sommer, J.**	Cognitive processes and judgmental strategies in belief updating
de Groot CUBE 216	CT	**Ralston, R.**	Generalizing categorization models as attractor networks yields powerful learning architectures
de Groot CUBE 216	CT	**Li, Y.**	Can the queueing model of visual search account for feature search?
de Groot CUBE 216	CT	**Turner, B.**	Inferring Constraints on Attention: An Across Species Analysis

Room	10:00-11:00 | Mental processes & health		
Révész CUBE 217	CT	**Jiawen-Liu, S.**	A Novel Approach Using Pairwise Choice Questions and Order Constraint Models
Révész CUBE 217	CT	**Lasagna, C.**	A drift diffusion modeling investigation of altered self-referential social perception in psychosis and bipolar disorder
Révész CUBE 217	CT	**Ghaderi-Kangavari, A.**	Exploring stimulus- and action-value reinforcement learning in Parkinson's disease

Room	10:00-11:20 | Neuroscience		
Donders CUBE 28	CT	**Stolle, C.**	Model selection for parsimonious whole-brain decoders: beyond cross-validation
Donders CUBE 28	CT	**Preusse, F.**	Nonstationarity of the hemodynamic response function in event-related functional magnetic resonance imaging
Donders CUBE 28	CT	**Krause, J.**	Massive generalized additive models of neurophysiological time-series
Donders CUBE 28	CT	**Steeghs-Turchina, M.**	Modeling EEG with axon delay times to analyze individual differences in cognition

Room	10:00-11:20 | Social cognition: Wisdom of the crowd		
Mellenbergh CUBE 219	CT	**Vanhasbroeck, N.**	Minds for Mobile Agents: A pedestrian model based on psychological principles
Mellenbergh CUBE 219	CT	**Wort, F.**	Distribution Inference and Surface Tracing (DIST): A computational model of ensemble perception
Mellenbergh CUBE 219	CT	**Angne, H.**	Why two heads together are worse than apart: A context-based account of collaborative inhibition in memory search
Mellenbergh CUBE 219	CT	**Lee, M.**	Using cognitive models to debias anchoring effects in wisdom of the crowd aggregation

Room	10:00-11:20 | ICCM: Learning processes		
Vuyk CUBE 220	CT	**Bennet, D.**	Genetically evolving verbal learner: a computational model based on chunking and evolution
Vuyk CUBE 220	CT	**Wilschut, T.**	Modeling Instance-Based Rule Learning in an Adaptive Retrieval Practice Task
Vuyk CUBE 220	CT	**Collins, M.**	Dissecting the Drivers of Change Points in Individual Learning: An Analysis with Real-World Data
Vuyk CUBE 220	CT	**Shahar, N.**	Exploring the Steps of Learning: Computational Modeling of Initiatory-Actions among Individuals with Attention-Deficit/Hyperactivity Disorder

11:20-11:40 | Coffee break

Room	11:40-13:00 | Symposium: Computational Models of Confidence and Metacognition		
de Groot CUBE 216	SY	**Guggenmos, M.**	ReMeta toolbox: inferring latent metacognitive parameters from confidence datasets
de Groot CUBE 216	SY	**Benwell, C.**	Sub-clinical psychiatric symptom dimensions are associated with shifts in metacognitive bias but not metacognitive noise

de Groot CUBE 216	SY	**Ceja, V.**	Select-a-frame: constructing comprehensive and comparable metacognitive behavioral profiles
de Groot CUBE 216	SY	**West, R.**	From perception to confidence: Leveraging natural image statistics

Room	**11:40-13:00 | Symposium: Deep learning and simulation-based inference for computational cognitive modeling**		
Révész CUBE 217	SY	**Sokratous, K.**	Unveiling the Hidden: Machine Learning Approaches for the Discovery of Latent Structures
Révész CUBE 217	SY	**Elsemüller, L.**	Integrating efficient sensitivity analyses into amortized Bayesian workflows
Révész CUBE 217	SY	**Kaper, R.**	Modeling the impact of stress on representation formation using variational autoencoders
Révész CUBE 217	SY	**Schumacher, L.**	Validation and comparison of non-stationary cognitive models: A diffusion model application

Room	**11:40-12:40 | Numeric cognition**		
Donders CUBE 28	CT	**Seitz, F.**	Investigating the cognitive processes underlying quantitative judgments: Insights from combining cognitive modeling and eye tracking
Donders CUBE 28	CT	**Sun, Y.**	Compressed Representations and Attentional Competition in Numeric Integration for Average Estimations
Donders CUBE 28	CT	**Castillo, L.**	Characterizing People's Sampling Engines Using Random Generation

Room	**11:40-12:40 | Context effects**		
Mellenbergh CUBE 219	CT	**Spektor, M.**	Testing context effects: How to have your cake and eat it, too
Mellenbergh CUBE 219	CT	**Davis-Stober, C.**	Testing the Additively Separable Representation of Utility Theories: An Experiment Evaluating Monotonicity, Transitivity, and Double Cancellation
Mellenbergh CUBE 219	CT	**Gelastopoulos, A.**	The disjunction effect does not violate the Law of Total Probability

Room	11:40-13:00 | ICCM: Neuroscience Models		
Vuyk CUBE 220	CT	**Sainz Villalba, L.**	A Neuro-Symbolic Implementation of Mouse Reward Timing Learning
Vuyk CUBE 220	CT	**Preuss, K.**	How to Match Cognitive Model Predictions with EEG Data
Vuyk CUBE 220	CT	**Frank, S.**	Simulating Event-Related Potentials in Bilingual Sentence Comprehension: Syntactic Violations and Syntactic Transfer
Vuyk CUBE 220		**Group Q & A**	

13:00-14:00 | Lunch break, ICCM Business meeting (CUBE 36)

14:00-15:00 | Keynote speaker: Gregory Cox			
Auditorium CUBE 1	KN	**Cox, Gregory**	Estes early career award lecture

15:00-15:20 | Coffee break

Room	15:20-17:00 | Symposium: Computational Computational Models of Confidence and Metacognition		
de Groot CUBE 216	SY	**Rausch, M.**	A comparison of static models of perceptual confidence and metacognition
de Groot CUBE 216	SY	**Hellmann, S.**	The importance of accumulation time in the computation of confidence
de Groot CUBE 216	SY	**Chen, H.**	Linear ballistic accumulator models of confidence and response time
de Groot CUBE 216	SY	**le Denmat, P.**	Learning how to compute confidence
de Groot CUBE 216	SY	**Gunay, E.**	Computational Modelling of Post-decisional EEG Markers Informing Confidence

Room	15:20-17:00 | Symposium: Deep learning and simulation-based inference for computational cognitive modeling

Révész CUBE 217	SY	**Radev, S.**	Amortized Bayesian inference with hybrid expert-in-the-loop and learnable summary statistics
Révész CUBE 217	SY	**Nunez, M.**	Using simulation-based Bayesian inference to explore the unidentified spaces of (neuro-)cognitive models
Révész CUBE 217	SY	**Huang, M.**	TogetherFlow: Bayesian simulation-based emergent attentional dynamics in room-oriented immersive systems
Révész CUBE 217	SY	**Bockting, F.**	Invertible neural networks for simulation-based prior knowledge elicitation
Révész CUBE 217	SY	**Lüken, M.**	Assessing the robustness of amortized Bayesian inference for evidence-accumulation models applied to different experimental designs

Room		**15:20-16:20 | General**	
Donders CUBE 28	CT	**Bompas, A.**	Decision versus non-decision time
Donders CUBE 28	CT	**Dai, J.**	Evidence accumulation is not essential for generating intertemporal preference
Donders CUBE 28	CT	**Chávez De la Peña, A.**	An EZ Bayesian hierarchical drift diffusion model for response time and accuracy

Room		**15:20-17:00 | Memory & perception**	
Mellenbergh CUBE 219	CT	**Salvatore, N.**	A neural network model of free recall and its connection to neural machine translation
Mellenbergh CUBE 219	CT	**Spicer, J.**	Mental Sampling in Preferential Choice: Specifying the Sampling Algorithm
Mellenbergh CUBE 219	CT	**Zhang, L.**	Integrating orthographic feature frequency with global matching models of recognition memory
Mellenbergh CUBE 219	CT	**Perquin, M.**	Tactile sensorimotor transformations are reliable over time, but do not generalize across tasks

Mellenbergh CUBE 219	CT	**Busemeyer, J.**	Comparison of Markov and quantum walk models of bistable perception

Room	**15:20-16:40 | Social cognition**		
Vuyk CUBE 220	CT	**Speekenbrink, M.**	State of Play: Interacting Latent Markov Chains in Repeated Games
Vuyk CUBE 220	CT	**Batzke, M.**	Exploring the Social and Temporal Dynamics of Striving for Cognitive Consistency in Political Belief Change
Vuyk CUBE 220	CT	**Fitch, A.**	The Value of Environmental and Health Outcomes under Delay and Risk
Vuyk CUBE 220	CT	**Malaviya, M.**	Teaching Functions with Gaussian Processes

Administrative meetings

IO: Invitation only, MO: Members only

Board meetings

All board meetings are by invitation only and will be held in the Business Room | Cube 36 room.

Date	Board meetings	
July 20 09:00 – 10:00 CEST	IO	CBB Editorial Board Meeting
July 20 13:00 – 14:00 CEST	IO	JMP Board Meeting
July 21 09:00 – 10:00 CEST	IO	WoMP Advisory Board Meeting
July 21 13:00 – 14:00 CEST	IO	SMP Executive Committee Meeting

Business meetings

All business meetings are open to all members and are strongly encouraged to attend. Meetings will be held in the Business Room | Cube 36 room except the SMP Business meeting, which will take place in the auditorium.

Date	Business meetings	
July 21 16:40 – 17:40 CEST	MO	SMP Business meeting
July 22 13:00 – 14:00 CEST	MO	ICCM Business meeting

Keynotes and awards

AW: Award, KN: Keynote

All the following sessions will be held in the Auditorium | CUBE 1 room.
All times are in CEST.

Date	Session	
July 20 12:00 – 13:00	KN	Keynote speaker: Iris Groen - ICCM
July 20 16:00 – 17:00	AW	Fireside chat: Rich Shiffrin (moderated by E.J. Wagenmakers)
July 21 14:00 – 15:00	KN	Keynote speaker: Iris van Rooij
July 22 14:00 – 15:00	AW	Keynote speaker: Gregory Cox - Estes early career award lecture

Keynote abstracts

Reclaiming AI as a theoretical tool for cognitive science

van Rooij, Iris
Radboud University, Nijmegen

Session:
MathPsych keynote speaker

The idea that human cognition is, or can be understood as, a form of computation is a useful conceptual tool for cognitive science. It was a foundational assumption during the birth of cognitive science as a multidisciplinary field, with Artificial Intelligence (AI) as one of its contributing fields. One conception of AI in this context is as a provider of computational tools (frameworks, concepts, formalisms, models, proofs, simulations, etc.) that support theory building in cognitive science. The contemporary field of AI, however, has taken the theoretical possibility of explaining human cognition as a form of computation to imply the practical feasibility of realising human(-like or -level) cognition in factual computational systems; and, the field frames this realisation as a short-term inevitability. Yet, as we formally prove herein, creating systems with human(-like or -level) cognition is intrinsically computationally intractable. This means that any factual AI systems created in the short-run are at best decoys. When we think these systems capture something deep about ourselves and our thinking, we induce distorted and impoverished images of ourselves and our cognition. In other words, AI in current practice is deteriorating our theoretical understanding of cognition rather than advancing and enhancing it. The situation could be remediated by releasing the grip of the currently dominant view on AI and by returning to the idea of AI as a theoretical tool for cognitive science. In reclaiming this older idea of AI, however, it is important not to repeat conceptual mistakes of the past (and present) that brought us to where we are today. This is joint work with Olivia Guest, Federico Adolfi, Ronald de Haan, Antonina Kolokolova, and Patricia Rich. The full paper is available here (https://osf.io/preprints/psyarxiv/4cbuv).

Modelling real-world visual perception with deep learning

Groen, Iris
University of Amsterdam

Session:
ICCM keynote speaker

Deep neural networks (DNNs) have emerged as powerful computer algorithms that achieve human-level performance on challenging tasks such as object recognition and language comprehension. This has opened up a new research field in which explanations of brain function are sought in comparisons between DNNs and human behaviour and brain activations. In this talk I will discuss why and how this computational modelling approach could indeed help us explain the brain, focusing specifically on the case of human visual perception of naturalistic real-world images and videos.

Models and Meaning: Coming Out as a Mathematical Psychologist

Cox, Gregory
University at Albany

Session:
Estes Award Winner

I love introducing myself to laypeople as a "mathematical psychologist" because they often view the term as an inherent contradiction between the strict formal world of mathematical and computational models on the one hand and the fuzzy ineffable realm of the mind on the other. By embracing that apparent conflict, I think mathematical psychology is in a unique position to help advance the science of cognition beyond the recent crises which have exposed issues in our experimental and statistical methods. Mathematical psychology has already played a large part in developing tools that expand access to Bayesian statistics and psychometrics, but I think it has an even more valuable part to play in advancing the psychological theories our methods are meant to test—by imbuing formal models with meaning and enabling meaning to be expressed via formal models. In this talk, I consider a number of issues I have encountered in developing mathematical models to express cognitive theories. These issues manifest, like mathematical psychology itself, as tensions between seemingly opposing ends of a continuum. These include some specific issues related to my own areas of research, like the tension between episodic and semantic memory; the tension between associations and the items they bind together; and the tension between neural and cognitive levels of description. They also include broader issues like the tension between statistical/descriptive models and causal/mechanistic models; the tension between quantitative fit and explanatory power; and the tension between models as psychometric tools versus expressions of theory. I make no attempt to resolve these tensions. Instead, I argue that the value of mathematical psychology lies in providing the language to articulate these tensions and to enable researchers to decide for themselves where they fall along these various continua in a given scientific context—to express what they mean in terms of models and to use models to help them explore what they mean.

Fireside chat: Rich Shiffrin (moderated by EJ Wagenmakers)

Shiffrin, Rich
Indiana University

Wagenmakers, EJ
University of Amsterdam

Session:
Fireside Chat

A discussion with Rich Shiffrin about his career as a mathematical psychologist. The discussion will be led by E.J. Wagenmakers.

Reinforcement learning modeling for human choice behavior

Shahar, Nitzan
Tel Aviv University

Katabi, Gili
Tel-Aviv University, Israel

Ben-Artzi, Ido
Tel Aviv University

Marcus, Maya
Tel-Aviv University, Israel

Elchayani, Shir
Tel-Aviv University, Israel

Session:
Workshop: Reinforcement Learning Modeling For Human Choice Behavior

Reinforcement learning (RL) algorithms have proven to be exceptionally effective in modeling human value-based learning and decision-making behaviors. This workshop offers an in-depth introduction to RL algorithms and their application in modeling human decision-making behaviors. Starting with the fundamentals, participants will learn model-free RL algorithms applied to a multi-armed bandit task. The workshop will then advance to explore two key extensions; (1) hierarchical RL modeling, where a sequence of action is required to complete a goal, and (2) model-based RL modeling where action-values are computed based on mental simulation of possible state transitions. Throughout the workshop, participants will engage in practical, hands-on coding exercises. These will include Bayesian parameter recovery to identify RL agents' parameters using Stan. Additionally, attendees will experience parameter estimation applied to existing human empirical data. The workshop is tailored for a wide audience from those with a basic understanding of programming and statistics to experienced researchers in cognitive modeling seeking to deepen their understanding of basic RL modeling techniques. By the end of the session, participants will have acquired basic theoretical knowledge and practical skills in implementing RL models, setting the stage for further exploration and application of RL in various domains of cognitive science and beyond.

How to publish and evaluate your model

Ritter, Frank E
Penn State

Session:
Workshop: How To Publish And Evaluate Your Model

This tutorial draws from a book in process about design patterns in cognitive modeling, tentatively titled Design patterns in modeling and HCI. It will be published by Oxford University Press.
"How to publish your model" provides general comments on publishing reports of models and the steps in modeling and simulation. It notes the importance of writing and of the final results. It describes the various types of outputs, including talks and publications. It provides a detailed process for handing the preparation, submission, and revision of a paper reporting a model, particularly about the importance of staying in touch with stakeholders. It also talks about how to present a model as well as providing some advice on how to write a conference paper and a journal article in these areas.
"How to evaluate your model" introduces the basic concepts in evaluating a model, which is done after describing the model and its behavior. After debunking the concept of proving a model, this chapter presents the case that you would like to do two fundamental things: show that the model is worth taking seriously, both to yourself and to others, and to know where to improve it. This chapter notes methods and design patterns for doing these two tasks looking at non-numeric, simple, and advanced methods that have been used, using a score card as a way to summarize the fit. It will also address interactions of these tasks with publishing your model.

Evaluating the effects of response scale resolution on confidence judgements: A Multiple Threshold Race model approach

Alaukik, Abhay
University of Florida

Odegaard, Brian
University of Florida

Heathcote, Andrew
Univeristy of Amsterdam

Kvam, Peter
University of Florida

Session:
Evidence Accumulation: Race Models

We evaluate the metacognitive properties of confidence and how response scales of different resolution affect it. Specifically, we used the Multiple Threshold Race model (MTR; Reynolds et al., 2021) to understand the placement of confidence boundaries and how they change across scales of different resolutions. In two studies, we tested how accurate people's confidence judgements are on a simple perceptual task: participants were asked to evaluate whether there were more blue or orange dots in a dynamic cluster. To understand the impact of response scales, participants rate how confident they are about that judgement. We manipulated the scale resolution so that it had 3, 4, 5, 6, 11, or 21 levels, as well as included a scale with continuous resolution. We also manipulated the difficulty of the task as well as included a speed vs. accuracy manipulation (whether speedier or more accurate responses was encouraged). Results show that reaction times follow Hick's law (1952) under standard conditions but violate the law under time pressure. Difficulty also affected participant responses: people were generally overconfident in high-difficulty conditions, but their overconfidence decreased as the resolution of the response scale increased. By modeling the data with the MTR model, we aim to understand the cognitive processes that constitute confidence judgements.

Examining the Psychological Significance of the Jumps in the Decision Process through Test-Retest Reliability Analysis

Ebrahimi Mehr, Mehdi

Shahid Beheshti University

Amani Rad, Jamal
Shahid Beheshti University

Session:
Evidence Accumulation: Race Models

In decision-making, the Levy flights model (LFM), an extension of the diffusion decision model, adopts a heavy-tailed distribution with the pivotal 'alpha' parameter controlling the shape of the tail. This study critically examines the theoretical foundations of alpha, emphasizing that its test-retest reliability is essential to classify it as a cognitive style measure. Our analysis confirms the alpha parameter's test-retest reliability across various occasions and tasks, supporting its role as a trait-like characteristic. The study also explores LFM parameter interrelations, despite low correlation among the other parameters (so representing distinct aspects of data), there is a pattern of strong correlation between alpha and threshold. Investigating the practice effect, our analyses indicate a consistent decrease in non-decision time, threshold, and often alpha across sessions, alongside the drift-rate increase. We also employ Bayesflow for parameter estimation, evaluating its precision with different trial counts. These findings provide valuable guidelines for future LFM research.

Modeling the stop signal task: further results on the copula approach

Jahansa, Paria
Oldenburg University

Colonius, Hans
Oldenburg University

Diederich, Adele
Oldenburg University

Session:
Evidence Accumulation: Race Models

The stop signal task is a popular tool for studying response inhibition. Participants perform a response time task (go task) and, occasionally, the go stimulus is followed by a stop signal after a variable delay, indicating that subjects should withhold their response (stop task). In the stimulus-selective version of the task, two different signals can be presented after the go signal, and subjects must stop if one of them occurs (stop signal), but not if the other occurs (ignore signal). A major challenge in modeling is the unobservability of stop signal processing if stopping is successful. In the dominant model, performance is hypothesized as a race between two stochastically independent random variables representing go and stop signal processing. An important prediction of all independent race models is that the distribution of reaction times to the go signal, without a stop signal being present, lies below the go signal distribution when a stop signal is presented after a certain time interval (stop signal delay). In previous work based on the statistical concept of copula, we have shown that observed violations of this prediction can be accounted for by dropping the stochastic independence assumption (Colonius, Jahansa, Joe & Diederich, CBB 2023). Here, we present further results on the distribution inequality for stochastically dependent race models with different types of marginal distributions and corresponding copulas.

Bias Against Levy Flight: What Happens When We Misspecify Levy Flight as Diffusion Model?

Hato, Tuba
Heidelberg University, Germany

Schumacher, Lukas
University of Basel

Radev, Stefan
Rensselaer Polytechnic Institute

Voss, Andreas
Heidelberg University

Session:
Evidence Accumulation: Race Models

Individuals may employ diverse decision-making strategies, and the Levy Flight (LF) model, developed by Voss et al. (2019), accommodates these variations through a fat-tailed process of evidence accumulation. Although the Diffusion Model (DM) is commonly used in modeling binary decision-making, we propose that in certain instances, the LF model could be a more faithful representation of the data-generation process. We aim to investigate whether a bias exists when the true data-generating model is LF and the DM is employed to interpret the data, and vice versa. To investigate this, we conducted an extensive simulation study using simulation-based inference with neural networks as implemented in the BayesFlow framework, an approach suitable for models lacking analytical likelihood functions, as the LF. Another aspect of our study examined the potential biases present in neural network estimates. To assess this, Stan was utilized as a benchmark for the neural estimators. A comparison of parameter estimates for the standard DM between BayesFlow and Stan revealed a close correspondence for both DM and LF data, thereby validating our methodology against a strong baseline. In terms of our substantive question, both BayesFlow and Stan revealed nearly identical estimation biases when fitting the DM to LF data: non-decision time was underestimated, boundary separation and starting point is overestimated in fast responses, and drift rate estimation deteriorated as drift rate increased. These results suggest that neural networks can closely approximate the true posteriors of DM, but these posteriors may exhibit notable biases when estimating the core DM parameters from LF-like data.

Is Evidence Accumulation Jumpy? A Lévy-Flight Model explains Fast Errors in Perceptual Decision Making

Voss, Andreas
Heidelberg University

Session:
Evidence Accumulation: Race Models

In the last decades, the diffusion model (Ratcliff, 1978) has become a standard model for fast binary decisions, as it is able to map data from many different cognitive tasks. The diffu-sion model assumes that binary decisions are based on continuous evidence accumulation with constant drift and Gaussian noise. However, recently, it has been suggested that mod-els with heavy-tailed noise distributions provide better fit especially for fast perceptual deci-sions. These so-called Levy-Flight Models of decision making are characterized by jumps in evidence accumulation. In the present study, the goodness-of-fit of the standard diffusion model and the Levy Flight model are compared for four different tasks. Specifically, partici-pants had to assess the direction of arrows (perceptual task) or the odd/even status of num-bers (numerical task). Both tasks were administered in a single stimulus condition and a multiple stimulus condition, whereat in the latter condition, the task was to indicate the dom-inating stimulus type. Following previous results, we expected more jumpiness in evidence accumulation for the easier conditions (i.e. the arrow task and the single stimulus condition). Results confirmed these assumptions.

The REM model of Shiffrin & Steyvers (1997) Predicts 2AFC and Four-way Classification (4WC)

Mohamed, Zainab
IU Bloomington

Meyer-Grant, Constantin
University of Freiburg

Shiffrin, Rich
Indiana University

Session:
Memory

After study of a list of items, recognition memory is usually tested with a single item, half from the list (targets, or OLD) and half not from the list (foils, or NEW). The present research tests the ability of existing models to generalize to new situations by using a novel paradigm: testing with two items, both OLD, both NEW, or one of each. Some tests used Two-Alternative Forced Choice (2AFC) in which Ss were asked to choose the item more likely OLD; other tests used four-way classification (4WC) in which Ss were asked to classify the two items as 1) both old, 2) both new, 3) left old, right new, or 4) left new, right old. Both choice probabilities (accuracy) and response time were measured. Each S studied lists containing 12 words, 24 words, 12 pictures, 24 pictures, or lists of 12 words randomly mixed with 12 pictures. After study of mixed lists, some tests were two words, some were two pictures, and some were one picture with one word. The choice probabilities in all these conditions were predicted well by the Retrieving Effectively from Memory model (REM) of Shiffrin and Steyvers (1997) using the 1997 parameter values. Signal-detection modeling (unequal variance Gaussian strength distributions) predicted the choice probabilities using different parameters for different conditions, but suggested that decisions are based on the ratio of strengths rather than raw values, similar to the way that REM uses odds based on likelihood ratios. Initial analysis and modeling gave support to the idea that REM can be extended successfully to predict response times.

How cognitive load and cognitive reflection impact probability judgments?

Pothos, Emmanuel

Busemeyer, Jerome
Indiana University

Huang, Adam
Indiana University

Session:
Memory

Sampling is pivotal in existing models of probability judgments, yet it harbors two unresolved questions: (1) the specific factors that affect sampling errors have not been thoroughly investigated; (2) whether there are judgment errors beyond sampling's reach remains unknown. Our study aims to tackle these gaps with two approaches. First, we suggest that sampling errors inversely correlate with cognitive reflection scores, indicating that intuitive thinkers are more susceptible to such errors than analytical thinkers. Second, we posit that an increased cognitive load could limit the ability to collect samples, thereby increasing sampling errors. Our exploration focuses on the impact of these two factors on probability and normality identities as presented by Costello and Watts (2014) and Huang et al. (2024). We evaluate how well current sampling models predict the relationship between the two factors and the identities. Additionally, we investigate whether some identities exhibit different responses to the two factors compared to others.

Semantic Similarity and Context Cues alleviate Set-size Effects on Long-Term Memory Retrieval Times

Haridi, Susanne
Helmholtz Institute Munich

Thalmann , Mirko

Schulz, Eric
Helmholtz Institute Munich

Session:
Memory

We all know the feeling of searching our memory for that one particular piece of information. However, if long-term memory (LTM) retrieval is indeed a search process, the time it takes to remember a specific memory should be strongly affected by two factors: 1. The number of memories and 2. the organization of these memories. We tested these assumptions and used retrieval times (RTs) to investigate how LTM is organized. Specifically, participants learned word pairs and we tested how LTM RTs for cued words are affected by the number of learned word pairs. Additionally, we also manipulated the semantic similarity of the words in a word pair using Word2Vec embeddings to test whether semantic similarity decreases search times in LTM. The validity of the Word2Vec embeddings was confirmed in a separate study, where we showed a high correlation (r = 0.81) with human pairwise similarity ratings. We found that RTs were indeed longer after learning more word pairs and that semantically similar word pairs could be retrieved faster. In a second study, we tested whether additional context cues during encoding and retrieval speed up RTs. Preliminary results suggest, that this is the case. However, in line with cue-overload theory, the benefit of the context cue depended on how many items were originally associated with a context cue. These findings are consistent with a search-based model of retrieval, illustrating its sensitivity to the number of memory candidates, while highlighting the role of the specificity of the cue in optimizing search performance.

Neurocognitive psychometrics of interindividual differences in working memory

Göttmann, Jan
University of Mainz

Schneider, Daniel
Leibniz Institut für Arbeitsforschung an der TU Dortmund

Schubert, Anna-Lena
University of Mainz

Session:
Memory

Measuring individual differences in working memory processes is challenging, particularly if one is interested in the question of which specific aspect of working memory capacity is most relevant for individual differences in cognitive abilities. Mathematical models can address this issue, as they are capable of mapping processes of interest with parameters that are mathematically derived from hypotheses about the nature of these latent processes. The Memory Measurement Model framework (M3; Oberauer & Lewandowsky, 2018) consists of a collection of such cognitive measurement models that isolate parameters associated with distinct working memory processes, such as the formation of bindings or the filtering of irrelevant distractors, in widely used paradigms like simple or complex span tasks. Based on simulations, we developed a series of experiments for different stimulus modalities, tailored to estimate the parameters of the M3 complex span models and to be concurrently used for electrophysiological research. We demonstrate that the estimated parameters are related to specific neurocognitive processes such as the P300 and the contingent negative variation and are capable of mapping individual differences in these processes. We will discuss how this neurocognitive psychometric approach enables more precise measurement of latent working memory processes and whether model parameters can be mapped to neurocognitive correlates.

Working memory, attention and executive control in digit span tasks

Potthoff, Ruben
Netherlands Cancer Institute

Schagen, Sanne
Netherlands Cancer Institute

Agelink van Rentergem, Joost
Netherlands Cancer Institute

Session:
Memory

A considerable number of non-central nervous system (non-CNS) cancer survivors face long-term cognitive impairments after successful treatment, which affects various domains of cognition. Two tests used to measure working memory and attention are the digit span forward and digit span backwards, which were computerized to assess cognitive deficits in cancer survivors. These tests are generally analyzed through all-or-nothing scoring, discarding potentially useful information from input data.
We aim to construct a novel model to separate various processes measured in the digit span tests. We investigate which cognitive processes are impaired in cancer survivors.
We use a computerized testing battery to gather input data from the digit span tests, and use partial-credit scoring based on Damerau-Levenshtein distance as the primary outcome measure. We formulate a hierarchical Bayesian cognitive process model which uses these data to identify three separate processes: Working memory capacity, i.e., the maximum span length an individual is able to reproduce and influences both forward and backwards performance; attentional control, which modulates forwards and backwards performance; and executive control, which exclusively modulates backwards performance. We compare these process outcomes between non-CNS cancer survivors and healthy controls, to investigate whether our model is more informative than traditional clinical measures.
The digit span tests can be separated into three distinct cognitive processes, which can then be used to compare patient populations to healthy controls. More generally, formal modeling allows for the extraction of more precise information in describing the cognitive deficits faced by patients.

Modeling the roles of epistemic and aleatory uncertainty in people's subjective perceptions of uncertainty.

Lob, Aaron
University of Zurich, Switzerland

Frey, Renato
University of Zurich

Session:
Risky Choice 1

An old debate in the decision sciences is concerned with the question of how different forms of uncertainty influence people's perceptions and hence their choices. One plausible classification distinguishes between aleatory uncertainty which refers to stochastic variability in outcomes and epistemic uncertainty which refers to a lack of knowledge of something that is, in principle, knowable. Although this distinction is commonly used, to date no study has systematically disentangled (1) whether people perceive these two forms of uncertainty differently, (2) whether their perceptions are independent or correlated, and (3) how the respective perceptions are associated with people's perception of a situation's general uncertainty. To answer these questions, we conduct an experiment with a 2 (epistemic uncertainty: low vs. high) x 2 (aleatory uncertainty: low vs. high) between-subjects design. We implement this design both in the self-report (vignette-based scenarios) and the task (incentivized lotteries) space to thus model the relationship between different types of perceived uncertainty. By modeling how an individual's perception of uncertainty changes as a function of source and degree of uncertainty, we intend to make at least two contributions. First, we inform researchers on how to investigate the distinct influence of types and perceptions of uncertainty on a decision maker's choices. Second, we aim to contribute to the debate on how to distinguish risk, uncertainty, and different flavors thereof.

The influence of probability versus utility on repeated mental simulations of risky events

There has been considerable interest in exploring how the utility of an outcome impacts the probability with which it is mentally simulated. Earlier studies using varying methodologies have yielded divergent conclusions with different directions of the influence. To directly examine such mental process, we employed a random generation paradigm in which all the outcomes were either equally (i.e., followed a uniform distribution) or unequally (i.e., a binomial distribution) probable. While our results revealed individual differences in how the utility influenced responses, the overall findings suggested that it is the outcomes' probabilities, not their utilities, that guide this process. Notably, an initial utility-independent bias emerged, with individuals displaying a tendency to start with smaller values when all outcomes are equally likely. Our findings offer insights into the benefits of studying the mental sampling processes and provide empirical support for particular sampling models in this domain.

Li, Yun-Xiao
University of Warwick

Falben, Johanna
University of Warwick

Castillo, Lucas
University of Warwick

Spicer, Jake
University of Warwick

Zhu, Jian-Qiao
Princeton University, United States of America

Chater, Nick
Warwick Business School, United Kingdom

Sanborn, Adam
University of Warwick

Session:
Risky Choice 1

Investigating Risky Choices With 'Fatal' Outcomes Using the Extinction Gambling Task

Maier, Maximilian
University College London

Harris, Adam
University College London

Kellen, David
Syracuse University

Singmann, Henrik
University College London

Session:
Risky Choice 1

An affect-based computational framework for modeling risky choice with nonmonetary outcomes

Pachur, Thorsten
Technical University of Munich

Fulawka, Kamil
Max Planck Institute for Human Development

Session:
Risky Choice 1

The development of formal models of decision making under risk has been shaped largely by decisions between options with monetary outcomes, with the most prominent model being cumulative prospect theory (CPT). Whereas CPT is good at describing choices between monetary lotteries, it shows poorer performance in the context of decisions between options with nonmonetary and nonnumerical outcomes (e.g., medications with possible side effects). We suggest that this may be due to affective processes and context-dependent evaluation—which are not considered in CPT—playing a larger role in nonmonetary than in monetary choices. We propose three psychologically motivated modifications to CPT's modeling framework to capture these differences: (a) representing the subjective value of a nonmonetary outcome by an affect rating (rather than a monetary equivalent); (b) determining the subjective affective value of an outcome relative to the value of the worst outcome in the choice problem; (c) assuming that the probability weighting for an outcome depends on the amount of affect triggered. We submit model variants of CPT implementing the proposed modifications to a model comparison in three empirical data sets. For choices between options with negative nonmonetary outcomes (medications with possible side effects), these modifications substantially improve CPT's performance relative to that of the original version of CPT. The same does not hold for monetary choices. Overall, in addition to fleshing out key differences in the processing of monetary and nonmonetary risky options, our work demonstrates how affective processes can be formally integrated within classical theories of decision making under risk.

How sampling strategies shape risky choice

Hof, Linus
Technical University of Munich

Zilker, Veronika
TUM School of Management

Pachur, Thorsten
Technical University of Munich

Session:
Risky Choice 1

When making decisions under risk, information about the options' payoff distributions is often initially limited and must therefore be actively gathered. Making such experience-based decisions not only requires a procedure for comparing options, but also a procedure for guiding and stopping information search. Although search, comparison, and stopping are elementary components of the decision-making process, rather little is known about how they might contribute to particular preference patterns. Here, we develop a computational framework to specify sampling strategies for experience-based risky choice in terms of a search, a comparison, and a stopping rule, and examine the choice patterns emerging under different settings of these rules. Our analyses demonstrate how descriptive hallmarks of decision making under risk–such as deviations from expected value (EV) maximization, risk aversion, and over- or underweighting of rare events–can arise from the operation and interplay of the building blocks that compose the sampling strategies. For instance, we show how frequent switching between options during search and a longer search process lead to more EV maximization and a linear weighting of outcomes and probabilities when the samples are integrated and evaluated according to a summary comparison rule. In contrast, we show how the same search pattern leads to systematic deviations from EV maximization, an S-shaped probability weighting function, and a highly compressed value function when the samples are integrated and evaluated according to a roundwise comparison rule. Moreover, our analyses reveal how sampling strategies produce different choice behaviors depending on the properties of the choice ecology.

Cognitive models of multi-response choice

Fernandez, Kianté
University of California, Los Angeles

Callaway, Fred
Princeton University

Karmarkar, Uma
University of California San Diego

Krajbich, Ian
University of California, LA

Session:
Evidence Accumulation: Multi-Attributes, Multi-Responses, And Complexity

The literature on value-based decision-making often focuses on single-item selections. However, many decisions like grocery shopping or forming a team, involve choosing multiple items. These "multi-response" decisions require selecting multiple options from a set. Despite their prevalence in everyday life, little work has examined the cognitive mechanisms underpinning multi-response decision-making. Our study extends the Sequential Sampling Model (SSM) framework to test competing strategies that people may use in multi-response choice. In our task, subjects were asked to choose one, two, or three food items out of a set of four. Our subjects generally chose their highest ranked foods (based on independent ratings). Interestingly, they also generally chose higher ranked items first. Subjects' response times for their first selected items were similar to their response times when choosing a single item. However, subsequent responses were made more quickly. Together, these results suggest that in multi-response choice people may evaluate their options in parallel, allowing them to gather support for multiple items at once, and leading to the fastest responses for the best items. Model simulations confirm that an SSM account can capture these patterns, while several alternative models cannot. Together, our work offers a starting point for studying the dynamics of multi-response decisions.

Value and contrast in evidence accumulation models

Mayaux, Damien
Paris School of Economics

Session:
Evidence Accumulation: Multi-Attributes, Multi-Responses, And Complexity

In evidence accumulation models of value-driven choice, drift rates are known to reflect the relative preference of the decision-maker over the alternatives. Although common evidence accumulation models - such as the DDM and LBA - are equally able to fit data for a given choice set, they generate diverging predictions about the effect of increasing the value of an alternative and their calibrated drift rates are not easily comparable.
In this paper, I clarify theoretically the relation between drift rates across evidence accumulation models. I characterize evidence accumulation models by their range - the set of choice and response time distributions that they can generate - and their contrast - the extent to which increasing the value of one alternative slows down the choice of another. Common evidence accumulation models have a similar range, as my simulations reveal, but a drastically different contrast.
Since the correct level of contrast is an empirical question, I propose a tractable framework to calibrate it on an existing model. I also give general conditions under which this approach is applicable. Evidence accumulation model with a similar range generate similar predictions once their contrast is properly calibrated. I calibrate a LBA model and its contrast on data generated by a DDM with varying alternatives values and find the level of contrast predicted by theory for a DDM.
Overall, this paper sheds a new light on the long-lasting debates on model equivalence and mimicry from the perspective of value-driven choice.

Analyzing the Impact of Choice Complexity on Risky Choices

Nie, Maohua
University of Basel

Olschewski, Sebastian
University of Basel

Rieskamp, Jorg
University of Basel

Session:
Evidence Accumulation: Multi-Attributes, Multi-Responses, And Complexity

The pervasive challenge of information overload often leads decision-makers to avoid complex options in favor of simpler to understand alternatives, even if the complex options are more rewarding. However, previous research only focused on the behavioral phenomenon of complexity aversion. Here, we provide a drift diffusion modeling approach to better understand how complexity affects decision making in a different experimental environments. In our experiment, we use compound lotteries to examine decision making not only between complex and simple options but also in situations where both options are either complex or simple. Through the application of drift diffusion models, we aim to elucidate the cognitive mechanisms at play during the decision-making process.

As results we found no support for complexity aversion when contrasting complex with simple options. However, comparing decisions between complex and simple options, we found effects of complexity on decision making in response times, choice consistency, risk taking, and the effect of rare outcomes (or skewness) on decisions. Building on these behavioral effects, we employed drift diffusion models to test the cognitive processes through which complexity affects decision-making. This approach reveals significant effects of complexity on risk preference, choice consistency, and the subjective interpretation of probabilities. The new experimental results and the computational modeling advance our understanding of how complexity impacts risk-taking behavior and delineates the cognitive processes involved.

Speed, accuracy, and complexity

Gonçalves, Duarte
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Session:
Evidence Accumulation: Multi-Attributes, Multi-Responses, And Complexity

Response time is often used as an indicator of how complex a problem is in various settings, such as lottery choice, loans, and portfolio selection. This is sometimes justified by is the observation that, in many cases, faster choices tend to be more accurate. Existing evidence suggests a more ambiguous relationship between speed and accuracy, wherein sometimes faster decisions are better, and in other instances slower decisions are more accurate.

In this paper, we reconcile this ambiguous relation between speed and accuracy by revisiting a standard Wald problem of optimal stopping. We show that whilst choice quality is monotone in problem complexity (noise-to-signal ratio), expected stopping time is inverse U-shaped. This suggests a nuanced relation between speed and accuracy: in simple problems, people choose fast and well; in slightly more complicated ones, they choose slower and less well; but if they become much more complicated, choices are necessarily worse, but response times are now faster. Extending our model to dynamic effort control, we uncover that this non-monotonicity also suggests restraint in using response times to infer ability: high ability individuals may choose faster in simple problems and slower in more complex ones. Moreover, we show that this non-monotonicity is a generic feature of models with costly information acquisition. Finally, we leverage our results to examine the effect of incentive distortion on behaviour. We find that incentive distortion is more effective in steering choices in more complex problems, opening the way to infer problem complexity from simple manipulations of incentives.

A computational framework to account for visual attention in multi-attribute decisions

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Session:
Evidence Accumulation: Multi-Attributes, Multi-Responses, And Complexity

The impact of visual attention on choice processes has been established over the last decades. Several studies are consistent with the view that visual attention increases the subjective value of the attended option. However, a few computational models have been proposed to investigate how attention and subjective values interact in multi-attribute choices. Moreover, these models disagree in terms of whether value is modulated by attention additively or multiplicatively. The additive theory states that the boost up subjective value depends only on gaze duration, and gaze on an option magnifies the subjective value at a constant rate. On the other hand, the multiplicative theory assumes that the magnitude of the attention-driven boost is value-dependent, and gazing at a high-value option yields a more significant boost in subjective value. Although there is a long debate on these two theories, recent studies have shown that both additive and multiplicative interactions between subjective value and gaze time may be essential for explaining empirical data and have suggested hybrid theories. For multi-attribute decisions, however, extant attentional models only consider the multiplicative interaction. This work introduces a new computational framework to account for attention in multi-attribute decisions. Our model assumes a hybrid attentional mechanism for the interaction between subjective values and gaze duration. We have tested the model on four datasets from various domains (e.g., clothing/brand, food/nutrition, food bundle, and money risk tasks). The results from the nested model comparison show that the proposed hybrid model works better than the other computational models.

Conceptions of status: A natural language processing approach

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Univeristy of Warwick

Walasek, Lukasz
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Brown, Gordon

Session:
Language & AI

People care about their status in the society. But how do they define status? What features and attributes does a high-status individual have? Traditional self-report methods are not well suited for uncovering the multidimensional and implicit meaning or meanings of status. We therefore used natural language processing (NLP) techniques to address these questions.

We used Word2Vec embeddings to predict status ratings (obtained from 161 participants) for 350 globally recognized names from the Pantheon 1.0 dataset. We achieved a correlation of .65 between actual and predicted status ratings. We also explored personality traits associated with perceived high status by multiplying the model's weight vector with embedding representations for trait words. We found that the "Intellect" construct (Goldberg, 1990) had the highest similarity, suggesting knowledge and intelligence are key perceived indicators of status for our (student) participants. Moreover, using a bottom-up approach by measuring the similarity between the weight vector and 10,000 common English words, we extracted the 100 adjectives most semantically related to status. Three clusters were identified: culture and art (e.g., cultural, musical, and classic), math and technology (e.g., mathematical, technological and physical), and nationalities/races (e.g., Indian, Asian and Brazilian).

We will also report results from an ongoing study that recruit a broader group of participants from Prolific. We will ask them to describe "high status" individuals in their own words, rather than rating given names. This study aims to explore how status is evaluated more generally.

Using LLMs to automate the analysis of verbal reports

Ungermann, Paul
Technical University of Munich

Ostrovsky, Tehilla
LMU Munich

Donkin, Chris
LMU Munich

Session:
Language & AI

In this presentation, we argue that verbal reports, often overlooked due to their perceived subjectivity and inefficiency for large-scale analysis, can be invaluable in understanding decision-making processes. Drawing from Mechera-Ostrovsky's framework, we demonstrate that such reports can validate the formal components in cognitive models, as well as explore their more implicit assumptions. To make the collection and analysis of verbal reports more efficient, we introduce a new, user-friendly platform, which is integrated in the jsPsych library, that uses advanced machine-learning methods to capture and automatically analyze verbal reports collected during an experiment.
We demonstrate the capabilities of this platform through a case study on a memory task. In this study, we provide a detailed explanation of our data evaluation process, which includes Speech Recognition, Auto-Summarization, and Text Vectorization. We will show how the text-vectorization step involves converting summaries of text into high-dimensional vectors, which then enables the use of numerical methods like clustering, hypothesis testing, and visualization. Our case study serves as a fundamental illustration, presenting a flexible structure that can be conveniently adapted to different pipelines, tasks, and applications. Overall, our approach provides a scalable and accessible alternative for translating qualitative data into quantified data, opening up new options for the way verbal reports can be utilized in cognitive research.

From Verbal Reports to Model Validation: Theoretical Framework and Application

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Session:
Language & AI

We introduce a novel theoretical framework that merges verbal reports with computational cognitive models. This approach leverages the context-sensitive capabilities of advanced large language models (LLMs) to analyze participants' verbal descriptions of their approaches to performing a task. To facilitate such an analysis, we have developed a JavaScript-based plugin for use with JsPsych that enables real-time speech recognition, where spoken reports are automatically converted into text and subsequently analyzed using LLMs. This tool significantly reduces the typical burden of analysing self-report data.
The talk will start by outlining the theoretical framework, emphasising its potential to enrich our understanding of cognitive processes through verbal data. It will then continue with discussing the functionalities of the plugin, ranging from its voice-to-text transcription capabilities, vectorisation, and the application of analytical techniques such as keyword extraction, clustering, and labelling. These features are pivotal for quantitatively assessing verbal data. Additionally, we will share insights from a pilot study conducted to evaluate the efficacy of our software, providing a comprehensive overview of its potential to enhance cognitive modelling research. In summary, this talk provides a generalisable roadmap for researchers interested in collecting verbal reports.

The Role of Episodic Memory in Storytelling: Comparing Large Language Models with Humans

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Rutgers University, New Brunswick

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Rutgers University, New Brunswick

Zhang, Qiong
Rutgers University, New Brunswick

Session:
Language & AI

We compare storytelling in GPT-3.5, a recent large language model, with human storytelling. Although GPT models are capable of solving novel and challenging tasks and matching human-level performance, it is not well understood if GPT processes information similarly as humans. We hypothesized that GPT differs from humans in the kind of memories it possesses, and thus could perform differently on tasks influenced by memory, such as storytelling. Storytelling is an important task for comparison as GPT becomes an increasingly popular writing and narrative tool. We used an existing dataset of human stories, either recalled or imagined (Sap et al., 2022), and generated GPT stories with prompts designed to align with human instructions. We found that GPT's stories followed a common narrative flow of the story prompt (analogous to semantic memory in humans) more than details occurring in the specific context of the event (analogous to episodic memory in humans). Furthermore, despite lacking episodic details, GPT-generated stories exhibited language with greater word affect (valence, arousal, and dominance). When provided with examples of human stories (through few-shot prompting), GPT was not able to align its stories' narrative flow with human recalled stories, nor did it match its affective aspects with either human imagined or recalled stories. We discuss these results in relation to GPT's training data as well as the way it was trained.

Varieties of selective influence: Extensions and surprises!

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Indiana University

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Session:
Mental Architectures & Information Processing

Abstract: All science, including psychological science, is subject to what Townsend and Ashby have called the principle of correspondent change which ensures that experimental manipulations act as informed agents with respect to predictions and testing critical theoretical features. Mostly, this type of program goes unspoken. Within the general field known as the information processing approach, S. Sternberg invented the additive factors method in which the aforesaid feature plays a major and explicit role. We call this approach a theory driven methodology because the scientist formulates a set of theories or models and then formulates experimental variables that will permit strong tests among the hypothetical alternatives. Our term for the general approach is systems factorial technology. Often, these tests can be accomplished with qualitative, non-parametric, distribution free methods, but our so-called sieve method advocates, once the initial qualitative steps are accomplished, a move to assessing more detail parametric versions of the model classes.
Over the decades, the meta-theory underpinning SFT and like approaches has evidenced dramatic growth in both expanse and depth. Particularly, the critical assumption of selective influence, testable to some extent, has received extensive and sophisticated treatment. The various central allied concepts are interlinked but do not form a simple linearly-ordered chain. This study carries on exploration of the central concepts and relationships and their implications for psychological research.

Learning in the Context of Partial Information

In our everyday lives, there are often more aspects of the environment than we can reasonably attend. As a consequence, we selectively attend to some aspects of the environment – usually those aspects which are most relevant to our goals – and ignore aspects that are deemed irrelevant. It follows then, that using selective attention can limit a learner's impression of an environment, because the information that is stored in memory is only a biased sample or partially encoded version of that environment. However, previous theories assume perfect and consistent access to all available dimensions, regardless of how attention is distributed. Here, we build upon existing models of categorization to illustrate how partial encoding can account for differences in learning. We use three benchmark datasets to demonstrate how the model can flexibly capture different learning strategies within the same task by creating a map of the corresponding representation. Most importantly, models equipped with partial encoding readily account for unique behavioral profiles suggesting failure of selective attention to relevant dimensions.

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Session:
Mental Architectures & Information Processing

Deriving critical tests of ACT-R using systems factorial technology with global model analysis

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Session:
Mental Architectures & Information Processing

Cognitive architectures (CAs) are unified theories of cognition which describe invariant properties in the structure and function of cognition, and how sub-systems (e.g., memory, vision) interact as a coherent system. An important role of CAs is integrating findings across many domains into a unified theory and preventing research silos. One downside of CAs is that their breadth and complexity create challenges for deriving critical tests of core architectural assumptions. Consequentially, it is often unclear to what extent empirical tests of CAs are driven by core architectural vs. auxiliary assumptions. To address this issue, we developed a methodology for deriving critical tests of CAs which combines systems factorial technology (SFT; Townsend & Nozawa, 1995) and global model analysis (GMA), forming what we call SFT-GMA. In SFT-GMA, GMA is performed within an SFT model space of qualitative model classes spanning four dimensions: architecture, stopping rule, dependence, and workload capacity. Constraints on the model space are derived from core architectural assumptions which may provide a basis for critical tests. To demonstrate the utility of SFT-GMA, we applied it to the ACT-R cognitive architecture (Anderson et al., 2004). Despite many degrees of freedom in the specification of parameters values, production rules, and declarative memory representations, SFT-GMA revealed that ACT-R's core architectural assumptions impose testable constraints on the SFT model space. In particular, ACT-R is incompatible with most parallel SFT models of perceptual processing. We believe that the use of theorem-based methods such as SFT-GMA have the potential to stimulate theoretical progress for CAs.

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Deciphering Decision-Making Efficiency: The interplay of reliability and credibility in automated information processing

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Session:
Mental Architectures & Information Processing

Effective information exchange plays a crucial role in attaining collaborative benefits, evident by dyads exchanging their confidence to reach integrated joint decisions. However, there is limited understanding of whether the credibility of automated information influences decision-making, particularly when decision makers were presumed to seek assistance from automation. In a categorization task, participants were randomly assigned to interact with automated aids varying in credibility and reliability for performing difficult and easy tasks. With the employment of the single-target self-terminating (STST) stopping rule in Systems Factorial Technology, participants' decision efficiency was measured by comparing decision performance with the assistance of the automated aid to a null model where the task was processed without any assistance. Results showed a robust validity effect (the performance discrepancy between the valid and invalid automated cues) in response times and accuracy when participants were aided by high-reliability automation. This effect was further amplified by the impact of high-credibility automated information, particularly in the context of difficult tasks. The STST capacity highlighted the significance of automation reliability, rather than credibility, in determining the processing efficiency of automated information. Specifically, the decision making with high-reliability information demonstrated efficient processing in difficult tasks when provided with valid information. Together, our findings suggested that credibility influences the attenuation of the validity effect when decision makers rely on highly reliable suggestions, yet it does not impact processing efficiency. Our research contributed to understanding the role of automation credibility and its interaction with reliability in automated information processing.

MSPN: A Modular Serial-Parallel Network for Computational Modeling of Response Time and Choice in Facial Recognition Across Composite, Part-to-Whole, and Other-Race Effect Paradigms

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Session:
Mental Architectures & Information Processing

The debate in face perception research revolves around holistic versus analytical processing. Evidence supports both methods, with neural and subjective data showing faces can be viewed both as wholes and by individual parts. This dual approach aligns with hierarchical object representation, where neural groups target specific visual traits. The challenge lies in merging these processes within a unified framework and connecting them to cognitive functions like memory and decision-making involved in recognizing faces. We propose a novel computational framework termed the Modular Serial-Parallel Network (MSPN), which synthesizes several perceptual and cognitive approaches including memory representations, signal detection theory, rule-based decision-making, mental architectures (serial and parallel processing), random walks, and process interactivity. MSPN provides a computational modeling account of four stages in face perception: (a) representational (b) decisional, (c) logical-rule implementation, and (d) modular stochastic accrual of information and can account for both choice probabilities and response-time predictions. As an exploratory tool, we utilized MSPN to validate facial theories across multiple paradigms: (i) In the composite face paradigm, the analyses revealed support for holistic encoding in aligned conditions and analytic encoding in misaligned conditions. The Congruency × Alignment interaction, often used to infer holistic processing, showed mixed results across models, raising concerns about its validity; (ii) in the part-to-whole paradigm analytic encoding and holistic encoding was equally successful in accurately capturing facial feature recognition patterns. MSPN effectively revealed shifts in facial perception when transitioning to object stimuli, but since serial and parallel modules show similar fits, exploring interactivity between facial features is crucial; (iii) in the other-race effect study we used MSPN as a theoretical tool in a face classification task exploring how people perceive faces from different races. The MPSN showing an impressive ability in fitting the individual choice response time distributions over other models. It suggests that facial processing can vary based on the task and doesn't always rely on holistic perception. The research didn't find a significant difference in how participants perceived faces of other races, possibly due to factors like sample size and adjustments made for individual differences in detecting facial features. Overall, MSPN provided detailed insights into cognitive processing dynamics, revealing the interplay between holistic and analytic encoding mechanisms. Our findings suggest a need for more comprehensive analyses beyond simplistic interaction measures. Additionally, MSPN serves both as an exploratory tool for refining the theoretical constructs in facial perception using validation/falsification operations and serves as a theoretical framework for exploring other perceptual and cognitive domains. Its versatility allows for generalization to diverse domains, offering a comprehensive approach to understanding complex cognitive processes.

The Dark Side of Sequential Testing: A Simulation Study on Questionable Research Practices

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Session:
Statistics

The replication crisis, characterized by issues such as inadequate sample sizes and questionable research practices (QRPs) including data peeking, has prompted the exploration of sequential testing procedures as a potential solution. Notably, Sequential Probability Ratio Tests (SPRTs) are highly efficient compared to traditional fixed designs. In our simulation of 120,000 datasets, the sequential samples were smaller than the fixed samples in 87% of cases. And on average, 56% fewer data points had to be collected with the sequential design. However, QRPs may also emerge in the context of SPRTs. Consequently, we carried out a simulation study in which we applied various strategies aimed at favoring the alternative hypothesis. These ranged from ostensibly well-intentioned or motivated reasoning to outright fraudulent manipulations, including multiple parallel sequential ANOVAs, subgroup and outlier analyses, adjustments in expected effect sizes, reordering of data, and selective data filtering based on their impact on likelihood ratios. Reflecting on our findings, our aim is to discuss the strategies we employed by assessing their severity, and to deepen the understanding of the risks associated with QRPs in the specific context of sequential testing.

Assessing the relevance of random effects for statements in mixed-effects models of the illusory truth effect

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Session:
Statistics

The illusory truth effect refers to the phenomenon that repeated exposure to a statement increases its perceived truthfulness. In truth-effect studies, binary judgments are usually aggregated within subjects, yielding proportions between 0 and 1. These values are then used as the dependent variable in an analysis of variance (ANOVA). However, this procedure has several limitations. First, it assumes that all statements in the study are homogeneous, even though they vary in terms of many properties. Second, proportions are subject to floor and ceiling effects, causing violations of model assumptions such as heteroscedasticity and impossible predictions beyond 0 and 1. Third, the ANOVA approach does not allow to add trial-level predictors. A solution to these issues is generalized linear mixed-effects models (GLMM). The random-effect structure can account for differences both in persons and statements, the use of a link function prevents the model from making impossible predictions, and trial-level predictors can easily be included. GLMM also offers theoretical benefits since the estimated regression coefficients can be interpreted as response bias and discrimination sensitivity in terms of signal detection theory. To compare the results of ANOVA and different GLMM specifications, we re-analyzed 22 openly available datasets from 2018 to 2024. The preliminary results show that GLMMs with random intercepts for subjects only do not solve the problems; conversely, they lead to higher rates of finding significant effects. However, once random intercepts for statements are added, p-values become more conservative.

Spurious correlations in cognitive models: Bayesian hierarchical modeling to the rescue

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Session:
Statistics

Cognitive models, such as evidence accumulation models, have become increasingly popular in individual differences research in psychology and neuroscience. By computing correlations among cognitive model parameters, researchers aim to understand how the cognitive processes they represent relate to each other and jointly determine performance. It is generally recognized that cognitive model parameters can be challenging to estimate due to their sloppiness, that is the strong within-participant correlations among the parameters encapsulated in the likelihood of the models. However, it is rarely acknowledged that sloppiness can lead to spurious between-participant correlations and hence result in incorrect substantive conclusions about individual differences. Consider, for instance, the diffusion decision model, a prominent cognitive model of speeded decision making. In the presence of limited between-participant variability in model parameters, the strong negative within-participant correlation between the response caution and non-decision time parameters can masquerade as a between-participant correlation, leading to the spurious conclusion that individuals with more cautious decision making are quicker at encoding the stimulus and executing the corresponding response. In this talk, we explore how single-level parameter estimation, Bayesian and non-Bayesian alike, can result in spurious between-participant correlations reflecting within-participant correlations rather than individual differences. We then show that the appropriately parameterized Bayesian hierarchical model can protect against spurious correlations. We discuss the consequences of this statistical artifact and offer recommendations for identifying and guarding against the resulting inferential biases.

Exploring non-linear trajectories in intensive longitudinal data: A comprehensive review of the available statistical methods

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Vogelsmeier, Leonie

Mulder, Joris

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Session:
Statistics

Traditional statistical approaches applied to intensive longitudinal data often assume linearity and stationarity. When applied to inherently non-linear processes such as second language acquisition, psychopathology onset and treatment, or emotional valence, these approaches will likely lead to biased conclusions. While various methods for modelling non-linearity like polynomial regression, regression splines, and non-linear dynamic structural equation modelling have gained popularity, many other techniques within the time series literature remain unexplored. Due to the diverse assumptions, inferential capabilities, and types of non-linearity that each of these methods can capture, researchers frequently face challenges in choosing the most suitable approach for their specific context. This talk aims to address this ambiguity by conducting an exhaustive review of the available techniques, ranging from data-driven tools, such as local polynomial regression and Gaussian processes, to fully parametric models within the state space model framework. Further, we conducted simulation studies to compare the efficacy of the different methods in capturing various types of non-linearity at different sample sizes, initially focusing on an n = 1 design. Lastly, we will illustrate what insights and inferences each method can provide by applying them to real intensive longitudinal experience sampling data. This comprehensive analysis intends to empower researchers to choose a statistical method that aligns with their theoretical considerations, research questions, and sample characteristics, when studying non-linear processes. We expect that this will reduce the bias induced by violating the linearity assumption in current experience sampling results and provide novel insights fostering theory development across domains.

Generalized Bayesian hierarchical structural equation modeling

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Session:
Statistics

Structural equation models (SEMs) are popular tools for investigating structural relationships among latent psychological constructs. In traditional applications, SEMs are estimated on summary scores aggregated across multiple measurements per individual, ignoring the hierarchical structure of the data and assuming that the individual-level data are normally distributed. This approach suffers from two shortcomings. First, failing to account for the nested data structure and the associated measurement uncertainty attenuates estimates of the structural relationships. Second, the assumption of normality is implausible in many applications and fails to provide a substantive psychological account of the processes that give rise to the data. Here we propose a Bayesian hierarchical SEM framework that addresses both limitations. Our approach allows researchers to flexibly model the individual-level data, ranging from the traditional normal distribution to generative cognitive models, such as evidence-accumulation or reinforcement learning models. The joint hierarchical estimation of the individual-level model, and the structural relationships among the latent constructs extracted from it, takes into account measurement uncertainty and hence safeguards against attenuation, and enables the use of Bayesian model selection techniques. We showcase how hierarchical SEMs can be used to test the latent structure of psychological constructs extracted from a psychological model fit to data obtained from multiple conditions, tasks, or data streams.

Hidden multivariate pattern analysis reveals the duration of encoding and decision processes in single-trial EEG data

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Session:
Evidence Accumulation & Neuroscience

Breaking down the nature and speed of information processing stages that occur between a stimulus and a response (i.e. reaction time, RT), has been a problem in psychology and neuroscience for more than a century. In decision-making, the RT is classically considered as a composite measure of at least the time required to encode the alternatives and the time required to decide upon them. In the present study, we used a perceptual manipulation that aimed at simultaneously decreasing this encoding time and increasing the decision time, together with a speed accuracy trade-off manipulation. We first show, that a drift diffusion model with a relationship between drift rates and the Weber-Fechner law accounts for these data, despite the fact that our manipulation should also decrease non-decision time. We then estimate the trial-by-trial duration of each RT component using the hidden multivariate pattern method on electroencephalographic data. This method uses the assumption of a recurrent sequence of multivariate patterns in the neural time-series across trials to estimate the onset of these patterns.
Among other things, we recover the expected opposite effect between encoding and decision time and show that the speed accuracy trade-off is more than a simple speed modulation of the RT and its components. This demonstration will show the value of detecting single-trial events in neural time series for answering research questions on mental chronometry and cognition in general.

A consensus guide to planning tasks for evidence accumulation modelling

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Innes, Reilly
University of Newcastle

Forstmann, Birte
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Session:
Evidence Accumulation & Neuroscience

Evidence accumulation models (EAM) are powerful tools for making sense of human and animal decision-making behaviour (i.e., choices and response times; RT). EAMs have generated significant theoretical advances in psychology, behavioural economics, and cognitive neuroscience, and are increasingly used in clinical research and other applied settings. Importantly, obtaining valid and reliable inferences from EAMs depends on knowing how to establish a close match between model assumptions and features of the task/data to which the model is applied. However, this knowledge is rarely made explicit in the EAM literature, leaving beginner EAM modellers to instead rely on the private advice of mentors and colleagues, and on self-directed study/experience with EAMs. We provide explicit, beginner-friendly practical guidance, based on expert consensus, for designing tasks appropriate for EAM modelling, for relating experimental manipulations to EAM parameters, and for collecting and preparing behavioural data for EAM analysis. By encouraging good task design practices, and warning of potential pitfalls, we hope to improve the quality and trustworthiness of future EAM research and applications.

Invariants of human behaviour revisited: Snapshot vs universal explanations in psychology

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Newell, Ben
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Donkin, Chris
LMU Munich

Session:
Philosophy & Theory

The generality of psychological theories is sharply divided by the basic-applied distinction. While basic research aims to uncover universal invariants of human thought and behaviour independent of the current moment (How does memory work? How do people solve problems?), applied research aims to provide explanations to how people solve more proximal problems (How well do eyewitnesses identify suspects in a line-up? What are the best methods to help students learn in the modern-day classroom?). I will argue that much of what is currently considered basic research is in fact applied. To make this point, I will draw on evolutionary epistemology – the idea that evolutionary logic underlies every knowledge-generation process, including biological and cultural evolution, and human creativity. Under this view, the invariant processes that basic research should aim to explain are those that increase and decrease variance and effect change over time (like the mutation and natural selection processes of biological evolution). Basic psychological research today, on the other hand, typically focuses on what people do right now and, as such, provides only "snapshot" explanations – e.g., cataloging the current strategies for memorising things or solving math or logic problems. I'll outline a more promising way towards universal psychological theories.

Comparing Bayesian and non-Bayesian accounts of human confidence reports: A computational replication study

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Rausch, Manuel
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Session:
Philosophy & Theory

Due to the ongoing replication crises in Psychology, it has bees been suggested that psychologists should make more wide-spread use of formal cognitive modelling. However, the large number of decisions researchers need to make during cognitive modelling raises doubts about whether results based on cognitive modelling will be easier to replicate. Here, we present a replication attempt of Adler and Ma's finding that heuristic models outperform Bayesian models in a orientation discrimination task with simultaneous confidence judgments (PLoS Comp Biol, 14(11), e1006572), suggesting that human perceptual decisions are not Bayes-optimal. Our analysis, using the authors' original data but reprogramming the modelling analysis from scratch, replicated Adler and Ma's main finding that heuristic models provide better fits to the data than the Bayesian models. However, our versions of the modelling analysis produced worse models fits than the results reported by Adler and Ma. In general, it seems rather difficult to replicate complex computational cognitive models without comprehensive details about the involved computations and the underlying computer code.

What makes formal modelling work?

Donkin, Chris
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Session:
Philosophy & Theory

There are a few purported reasons for why formal models improve the quality of the theories they implement. For example, building a model can make both the assumptions and the implications/predictions of a theory explicit and clear. While many such features are necessary, they are not sufficient for theoretical progress. I'll argue that building and testing formal models leads to better theories because the process of doing so can help hold the theory accountable to what has been observed (data) and to what else is known (other theories). Interestingly enough, many of the norms in the mathematical psychology community work in support of this goal, and the point of this talk is to make it explicit why they are important.

Understanding Race Bias in the Decision to Shoot with an Integrated Model of Decision Making

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Cesario, Joseph

Liu, Taosheng

Session:
Real-World Decisions

The shooting of unarmed Black males by police officers is a topic at the forefront of public awareness in the U.S. today. It is widely believed that police shootings reflect racial bias on behalf of officers, which erodes public trust and reduces policing effectiveness. We introduce a novel framework—the Attention-integrated Model-based Shooting Simulator (AiMSS)—to study how race, suspect behavior, and policing scenarios impact police officers' decision to shoot. The AiMSS combines computational models of decision making, visual psychophysics, eye-tracking methods, social measures of affective evaluations, and an immersive decision simulator to map the processes underlying a police officer's decision to shoot. We will summarize work from across several datasets with police officers completing a first-person shooter task in the AiMSS. Overall our behavioral and cognitive modeling results reveal that (a) policing scenarios and suspect behavior played an essential role in officers' decisions; (b) that errors are higher for unarmed than armed suspects, with some evidence for greater errors for Black vs White suspects; (c) this race effect is determined partly by an initial bias and diminished sensitivity during the decision, which are linked to perceived threat; and (d) training largely mitigated these race effects. This work provides a novel method for understanding the mechanisms underlying the decision to shoot, in terms of how different sources of information are integrated and how they impact different components and stages of decision making.

Modeling overtaking decisions in dynamic traffic interactions using generalized drift-diffusion models

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Session:
Real-World Decisions

Computational models of behavior are key in enhancing road safety by offering insights into human behavior that extend beyond empirical studies. Particularly, generalized drift-diffusion models (GDDMs), that is, DDMs with time-varying drift rates and decision boundaries, have deepened our understanding of decision making in traffic interactions. However, the application of GDDMs to traffic decisions has mostly focused on scenarios in which the decision-maker is stationary and the other traffic participants move with constant velocities. This restricts the application of such work in real-world traffic contexts in which the decision maker is often moving during the decision-making process and the other traffic participants may exhibit time-varying dynamics. To address this gap, we developed a GDDM-based account of human drivers' decision-making during overtaking maneuvers. In a driving simulator experiment (N=30), we varied the size of the gap available for the participants to overtake a leading vehicle. We assessed how this gap size and the dynamics of an oncoming vehicle impacted the decision outcomes and response times of the participants. Our empirical findings underscore the critical role of initial distance, time-to-arrival, and velocity of participants' vehicle in overtaking decisions.
By fitting four candidate GDDMs to the observed data, we found that participants' behavior was best described by a model hypothesizing dynamic drift rate, constant decision boundaries, and a decision bias dependent on the initial velocity of participants' vehicle. Overall, our findings highlight the potential of drift-diffusion models with time-varying components for further advancing the understanding of human behavior during dynamic traffic interactions.

Exploring the associations of diffusion decision model parameters with socioeconomic success

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Session:
Real-World Decisions

Cognitive process models such as the diffusion decision model allow researchers to estimate a set of parameters from empirical response times and accuracy data obtained in binary decision tasks. These parameters can then be used to quantify individual differences. They are thought to reflect, for example, a person's speed of evidence accumulation or decision caution in a certain task. Recently, researchers have become interested in how the model parameters might be related to other measures of individual differences, specifically general intelligence. For the drift rate parameter, higher parameter estimates seem to be linked to higher intelligence scores. However, cognitive abilities such as general intelligence are known to predict socioeconomic success (e.g., educational attainment, job prestige, income). If drift rates reflect a type of cognitive ability, they should also exhibit similar patterns. We thus studied the associations of diffusion decision model parameters with several indicators of socioeconomic success in a very large sample of online implicit association test data (Project Implicit; N > 5,000,000). We found robust associations between diffusion decision model parameters and indicators of socioeconomic success marked by small effect sizes. Our results highlight the utility of big data approaches in the field of cognitive modeling that have only recently become practically feasible through novel simulation-based inference methods.

To compete, or not to compete, that is the question

Lo, Chi-Fai

Ip, Ho-Yan

Session:
Real-World Decisions

How much debt and how much equity firms choose to finance their operations by balancing the costs and benefits is a fundamental question in corporate finance. The dynamic trade-off theory of capital structure suggests that a firm selects an optimal ratio of its liability to asset value (i.e. an optimal leverage ratio) to balance the dead-weight costs of bankruptcy and the tax saving benefits of debt. In other words, in the presence of adjustment costs, firms try to set relatively stable targets but tolerate deviations from these targets as long as leverage ratios stay within their target zones. Inevitably, such behavior is expected to affect the dynamics of leverage ratios. To assess the extent to which and how leverage dynamics are driven by such behavior, we apply a modified version of the Leaky Competing Accumulator model of decision making, which allows cooperation in addition to competition among firms, to investigate the dynamics of corporate leverage ratios and determine the target leverage ratios. Since the multi-firm joint probability density function of leverage ratios is known in closed form, a likelihood function can be constructed and thus model-fitting against empirical data becomes feasible. In both automotive and integrated oil industries firms are found to cooperate to fix their target ratios, and competition dominates between conventional automotive companies and electric car companies. Moreover, analytical default probabilities of these firms are available and their default risk can be estimated. Hence, the impact of climate-change policy on these firms are examined as well.

Pinocchio disassembled: Hierarchical diffusion modeling of the cognitive cost of lying

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Session:
Real-World Modeling

Telling a lie is more cognitively demanding than telling the truth. Support for this notion comes, inter alia, from instructed-lying paradigms showing that untruthful responses are slower than truthful responses. However, conventional measures of the cognitive cost of lying are typically collapsed across response categories and ignore error trials and accuracy, focusing only on average latencies of correct truthful and untruthful responses. To overcome the limitations of conventional approaches and disentangle the mechanisms underlying response behavior in instructed-lying paradigms, we propose to analyze data with a drift diffusion model. The diffusion model considers the full response-time distributions for both correct and error responses, thus making use of all available information. Using a Bayesian hierarchical diffusion model to analyze data from a Sheffield Lie Test, we find that the model's drift-rate parameter provides for a reliable measure of the cognitive cost of lying. Moreover, we find that truth-vs-lie instructions elicit a response bias that may confound conventional measures that fail to account for it. Thus, our results indicate that the diffusion model constitutes a promising means to analyze data from instructed-lying paradigms and that it offers intriguing avenues for future research on the cognitive mechanisms of lying.

A Reciprocal-Practice-Success (RPS) model of free practice

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Session:
Real-World Modeling

Many learning scenarios involve free practice where learners have the freedom to initiate and stop practice whenever they want (e.g., hobbies and Massive Open Online Courses (MOOCs)). However, a major concern in free practice learning are high dropout rates. Inspired from the literature on learning curves, forgetting curves and motivation-achievement cycles, we propose the Reciprocal-Practice-Success (RPS) model of learning 'in the wild'. We discuss the rationale behind each component of our model where Success and Practice form a mutually reinforcing positive feedback loop.
Through simulations, we show how long term learning outcome is sensitive to the shape of the learning curve; with S-shaped learning curves leading to either expertise or dropout. We also provide a dynamical systems approximation for the RPS model which has a similar qualitative behaviour. Through a bifurcation analysis of two controllable learning parameters - minimum practice rate and success sensitivity, we show what interventions can work to prevent quitting.
Next, we show the qualitative results are robust to different forms of the forgetting curve and more realistic extensions to the basic model. We end with a discussion of how our model complements different theories of motivation and self-regulation, with some proposals to reduce quitting in free practice.

Framing the Exploration-Exploitation Trade-Off: Distinguishing Between Minimizing Losses and Maximizing Gains

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Session:
Reinforcement Learning

In situations demanding loss avoidance or gain maximization, individuals must possess a profound understanding of the rules and regularities in their environment. However, exploration behavior varies across such scenarios. Past research has been inconclusive regarding the impact of a loss compared to a gain domain, particularly when exploration involves potential costs. In contrast, the current project centers on scenarios where subjects receive positive or negative rewards while exploring the environment or exploiting their knowledge. Participants engaged in a Multi-Armed Bandit task in three conditions: only gains in the environment, only losses in the environment, and a mixed condition involving both gains and losses. Notably, participants exhibited reduced exploration in the gain domain compared to the loss domain, with the mixed domain falling in between. Interestingly, participants performed best in the mixed domain. Computational modeling of participants' choice behavior revealed that individuals tend to underestimate outcomes of unchosen options in the gain domain and overestimate them in the loss domain. This pattern of findings could be attributed to the effects of absolute gains and losses or the effects of outcomes being relatively better or worse than the initial expectations.

A two-drift race model of human habits

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Session:
Reinforcement Learning

Psychologically, habits are defined as the reward-independent, stimulus-response relationships which form when identical actions are repeated often. These behaviours were originally studied in animals, and Hardwick et al. (2019) recently developed a paradigm to identify habits in humans. They hypothesised that human habits may be detected when participants are forced to act too quickly for conscious (goal-directed) control to be applied. They trained participants extensively on a stimulus-response mapping, and then the mapping was reversed. When participants were tested post-reversal, their behaviour changed depending on how rapidly they needed to react. Specifically, participants made more 'habitual' errors, i.e., choosing the original response, when forced to respond within 300-600ms. Hardwick et al. proposed that parallel accumulators were responsible, wherein the goal-directed system is initiated after a delay.

However, no formal mathematical model exists that instantiates this proposal and allows for multiple drift rates which change both across (via reinforcement learning) and within (parallel accumulators) trials.

In this paper, we present a novel 2-drift race model, and calculate the probability of reaction times and choices so it can be efficiently fitted to data from the paradigm by Hardwick et al.

To test their proposal, we compare the quality of fit of a single-drift Q-learn race model and that of our model, in which habit and goal-directed actions accumulate independently. Furthermore, the best fit parameters of the 2-drift model can provide several key insights into, and quantifiable measures of, the mechanistic structure underlying the differences between individuals' reliance on habits, undetectable in behaviour alone.

How General Are Individual Differences in Exploration Strategies?

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Witte, Kristin

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Session:
Reinforcement Learning

The explore-exploit dilemma is ubiquitous in everyday life: Should you go to the cafeteria again or try out the new restaurant around the corner? Researchers have proposed three strategies for how humans solve this dilemma: value-guided exploration, directed exploration, and Thompson sampling, which can be inferred using computational modeling. Behavioral research conducted over the last two decades suggests that people use a mixture of all three strategies to solve the explore-exploit dilemma. We collected responses from 200 participants (after exclusions) to a set of three commonly used few-armed bandit tasks before and after a six-week period to examine the reliability and validity of the three strategies. The currently accumulating results can be summarized as follows: First, identifying all three exploration strategies is not possible in these relatively simple bandit tasks, because the strategies are too highly correlated with each other. Second, not every task motivates exploration to the same extent introducing potential task-based variability into the measurement of the remaining two strategies. To remove this task-based variability from the measurement, we present an attempt to extract higher-order factors of value-guided and directed exploration using the responses from all three few-armed bandit tasks. Third, we contrast the retest reliability, convergent validity, and external validity of these latent factors with those of task-based performance measures. While behavior can be measured reliably in all three tasks and is correlated across tasks, the reliability of the model parameters is lower. The implications for the importance of exploration as an explanatory cognitive construct are discussed.

Understanding the structure of fluctuations in decision making

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Session:
Reinforcement Learning

Humans evolved in non-stationary environments, which require continuous adaptations of behavior to change. Decision making is, on the other hand, often studied in highly controlled experimental paradigms where the environment is mostly stationary. We propose that adaptive mechanisms continue to act in stationary environments and cause systematic fluctuations in performance from trial to trial. We develop and test a set of formal decision-making models that embrace adaptive mechanisms. Specifically, participants use reinforcement learning to estimate their own performance and the statistical structure of the stimuli on which decisions are based. These estimates subsequently influence evidence-accumulation-model parameters. In four datasets, we show that these mechanisms can explain the occurrence of post-error slowing and choice biases related to stimulus sequences, respectively. We argue that including adaptive mechanisms in evidence-accumulation models is a promising way forward to understanding not only how choice behavior changes across time, but also why it changes.

Decomposing financial decision-making with feedback

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Olschewski, Sebastian
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Session:
Risky Choice 2

The literature suggests that profit-harming trading behaviors are driven either by beliefs or preferences, while the relative contribution of each is unclear. We address this question by using computational modelling to determine whether belief formation or preferences better explain these decision patterns.
We analyzed a dataset of 192 participants who completed an investment task over 150 rounds. We observed that individuals tended to hold the asset more frequently than shorting it, were not invested in a number of rounds, and reacted slowly to price changes.
We defined risk-neutral Bayesian updating as our benchmark model and investigated the improvement of models along beliefs and preferences, based on a selection of well-established mechanisms. We tested all models that included combinations of both dimensions by changing belief formation mechanisms through reinforcement learning and differential updating for gains and losses, and by incorporating preferences such as risk preferences and loss aversion.
Model comparisons show that modelling belief mechanisms was much more important than preferences. Reinforcement learning and differential learning in gains and losses showed strong effects. Risk and loss preferences, and even their combinations with different types of beliefs, led to only small refinements. Inspired by the importance of learning, we tested whether people learn not only by reward, but also by repetition, thereby building habitual preferences. Implementing habits produced strong effects across all mechanisms used to form beliefs.
The good fit of the augmented RL model together with habitual tendencies to our data demonstrates the crucial role of learning processes in financial decisions.

Risk Seeking and Risk Aversion in Choices and Valuations from Experience

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Scheibehenne, Benjamin
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Session:
Risky Choice 2

Many important decisions are based on experience. Recently, the experimental paradigm of sampling a fixed number of outcomes, and afterwards making one consequential decision has received much attention in the decision-making literature. A puzzling phenomenon in this literature was that participants systematically chose the higher-variance option (e.g., Ludvig & Spetch, 2011; Tsetsos et al., 2014), that way contradicting classical work in decision-making concluding that people are risk averse for symmetrical outcome distributions. Here, we examined the robustness of this phenomenon in three experiments (sample size at least 176 per experiment). We varied whether single valuations came directly before choice task or were separated from each other; whether sequences were presented simultaneously or sequentially; and whether participants chose/valued two or four sequences per block. In all experiments, participants were risk seeking or risk neutral in the choice tasks, but risk averse in single independent valuations of the same outcome sequences (certainty equivalents). With computational modeling we show that the effect of choosing high-variance options can be explained through the comparison process between the presented outcomes in choices. In contrast, in single valuations, a noisy compressed mental number line explains the data best. We conclude that risk taking behavior must not necessarily indicate risk seeking or convex mental number lines, but rather can be explained through the process of outcome comparison during information sampling. Therefore, to understand risk taking across different answer modalities and contexts, it is crucial to explicitly model information processing.

Choose for others as you would choose for yourself? A layered analysis of probabilistic preferential choice

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Yang, Xiaozhi
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Session:
Risky Choice 2

The present study examines the effect of social distance on choice behavior through the lens of a probabilistic modeling framework. In two identical experiments, conducted three weeks apart, participants made incentive-compatible choices between lotteries in three different social distance conditions: self, friend, and stranger. We conduct a layered, within-subjects analysis that considers four properties of preferential choice. These properties vary in their granularity. At the coarsest level, we test whether choices are consistent with transitive underlying preferences. At a finer level of granularity, we evaluate whether each participant is best described as having fixed preferences with random errors or probabilistic preferences with error-free choices. In the latter case, we further distinguish three different bounds on response error rates. At the finest level, we identify the specific transitive preference ranking of the choice options that best describes a person's choices. At each level of the analysis, we find that the stability between the self and friend conditions exceeds that between the self and stranger conditions. Stability increases with the coarseness of the analysis: Nearly all people had transitive preferences regardless of the social distance condition, but very few had the same preference ranking in every social condition. This pattern of results replicated across the two experiments. Overall, while it matters whether one makes a choice on behalf of a friend versus for a stranger, the differences are most apparent when analyzing the data at a high level of granularity.

Episodic retrieval of cognitive control demand: A computational model

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Ghent University

Holroyd, Clay Holroyd
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Session:
Executive Functions & Cognitive Control

Humans can satisfy a large variety of abstract goals, such as driving to work or doing the weekly grocery shopping. This requires the maintenance of contextual information to guide neural information processing through top-down mechanisms (Miller & Cohen, 2001). Functions subserving this ability are collectively referred to as "cognitive control". Experimental investigations of cognitive control often present multi-dimensional stimuli with potentially conflicting information (e.g. the Stroop task or the Flanker task) or require switching between multiple tasks with different response demands for the same stimuli (e.g. task-switching studies). Previous work has found that allocation of cognitive control in these tasks is dynamic, adjusting to recent history (e.g. Gratton et al, 1992), but also long-term expectations (e.g. Bugg, 2014; Siqi-Liu & Egner, 2020) and item-specific expectations (e.g. Bugg et al., 2011; Chiu & Egner, 2017). In three new experiments, we show how "temporal context" (Howard & Kahana, 2002) can be seen as a primary driver of cognitive control allocation and develop a novel computational model that can explain these and several previous effects (Gonthier et al., 2016; Dignath & Kiesel, 2021) that earlier models (Botvinick et al., 2001; Verguts & Notebaert, 2008; Lieder et al., 2018) cannot account for.

Is focusing enough in category learning?

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Session:
Executive Functions & Cognitive Control

We examined whether selective attention, which is mainly theorized as the ability to focus on the category-relevant dimension, is a sole construct in understanding category learning. As the attention literature dissociates selective attention into focusing and filtering, we argue that filtering is another component that should be considered to fully understanding category learning. In the study, we provide an experimental paradigm that can dissociate filtering from focusing. By utilizing the paradigm along with collecting individual attention control measures, we show that filtering is related to the ability to inhibit irrelevant information. We also present that computational models (e.g., ALCOVE) that incorporate selective attention only as an ability to focus can not explain the results from the current study.

How do we avoid doing or saying the wrong thing at the wrong time: exerting cognitive control during and after accumulation of internal evidence.

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Moran, Rani
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Session:
Executive Functions & Cognitive Control

The ability to adapt verbal and behavioral output to current goals depends on various cognitive control mechanisms. The distinction among different control mechanisms often relies on their differential effects on response latency, which can be formalized using evidence accumulation models. Indeed, previous research suggests that cognitive control can modulate different components of evidence accumulation, including the rate of evidence accumulation and the amount of evidence required to reach a threshold. However, our subjective experience of exerting control often involves the experience of withholding the expression of a response that has already won this internal race. Such post-accumulation inhibition is especially relevant for behaviors that depend on memory retrieval, as in the case of free recall, semantic fluency, and the free association task. Thus, whereas the dynamics of memory retrieval can be formalized as a race among competing memories, the verbal expression of a retrieved memory could be inhibited if it turns out inconsistent with goals or task instructions (e.g., a word that has already been reported when such repetitions are prohibited). I will present a recently developed tractable model formalizing post-accumulation inhibition (semi-Markov process model). I will then demonstrate evidence for the involvement of post-accumulation inhibition in a free association task, highlighting its specificity to cases where the control criterion does not depend on evidence strength (i.e., when repeated associations are prohibited but not when weak associations are prohibited). I will conclude by discussing the implications of ignoring post-accumulation inhibition in other tasks involving cognitive control demands.

Choice models for the Dual-Modes of Cognitive Control task battery.

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Session:
Executive Functions & Cognitive Control

We report the development of evidence-accumulation models (EAMs) for a large data set from 128 participants performing tasks from the Dual Modes of Cognitive Control (DMCC) battery. Each participant performed two replications of 15 approximately half-hour sessions over two three-week cycles (Tang et al., 2023). DMCC is designed to probe individual differences in two modes of controlling choices, anticipatory ("proactive") and choice-stimulus-driven ("reactive"). The battery consists of four tasks, two requiring binary manual responses, Task Switching (consonant/vowel or odd/even choices) and Sternberg (positive vs. negative for presence on an immediately preceding study list). Another, the AX-CPT task, adds a no-go choice to a binary manual response task, and the fourth, a Stroop task, requires an 8-choice vocal colour-naming response. Each task has a baseline form and two variants incorporating manipulations encouraging proactive and reactive processing. Although EAMs with a race architecture can handle the diverse response types in a single framework, estimation challenges arise in providing a comprehensive account of performance in all conditions at the individual level because some reactive and proactive manipulations have very few responses even in this large data set. We attempt to address these challenges using hierarchical Bayesian modeling and parameterizations that balance parsimony, theoretical informativeness, and descriptive adequacy. We apply this approach to examine the reliability with which reactive and proactive control are measured and compare the outcomes to descriptive analyses employing descriptive measures based on a subset of each participant's trials reported by Snijder et al. (2023).

Exploring latent processes of human generalization via computational modeling

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KU Leuven

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Session:
Mental Representation

In our daily lives, encountering exact replicas is a rarity due to the ubiquitous presence of variability. As humans, we possess the remarkable ability to extrapolate from past experiences and adapt to diverse contexts, even when they are not identical. However, the mechanisms underlying this transfer process remain largely enigmatic, partly because current investigations often assume that variability is confined solely to the external features of physical inputs. This overlooks the intricate dynamics involved in how organisms interpret and process the physical world. To address this gap, we developed a computational model that amalgamates error-driven learning and similarity-based generalization processes. By integrating these processes, we endeavor to unravel the underlying mechanisms that govern our ability to generalize across diverse contexts. Presently, the three studies we have conducted with the computational model show that learning and mental representation are indeed important sources of adaptive behavior, that during the generalization process, mental representation is often probabilistic, inferential, and dynamic rather than static, and that mental representation during generalization process has specific temporal dynamics which are context-dependent.

Recovering individual mental representations of facial affect using Markov Chain Monte Carlo with People and Gatekeepers

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Tsvetkov, Chris
University of Warwick

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Session:
Mental Representation

People's mental representations of complex stimuli, such as facial expressions, are difficult to elicit. To address this challenge, methods such as Markov Chain Monte Carlo with People (MCMCP) integrate human decision-making into computer-based sampling algorithms. However, MCMCP suffers from slow convergence due to the high-dimensional sample space and inefficient navigation, making it impractical for recovering representations of individuals. Here, we extend MCMCP by combining it with an adapted Variational Auto-Encoder (VAE) that addresses the problem of slow convergence in two ways: 1) it usefully represents the facial expression of images in only three latent dimensions, and 2) it acts as a gatekeeper, using its own domain knowledge to quickly reject less useful trials to save participant effort. We tested this approach in a new experiment (N=90) on facial affect comparing baseline MCMCP (in a 157-dimensional PCA space) against both MCMCP in the 3-dimensional VAE latent space and MCMCP with a gatekeeper (MCMCPG) in the same VAE latent space. MCMCPG converged substantially faster than the other methods, generally in less than 200 trials, and the average recovered face was judged to be more representative than those from PCA and those from past work. Further analyses also revealed the extent of individual differences in facial affect representations, which could partially account for individual differences in decision-making. Our study demonstrates the potential of MCMCPG for investigating human representations at the individual level. It also provides a promising framework for linking machine intelligence with psychological experiments to enhance our understanding of human cognition.

State-independent and outcome-irrelevant model-free learning

Shahar, Nitzan
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Session:
Mental Representation

Natural environments are feature-rich and only a subset of these features is considered to predict action-outcome associations. To enable accurate action-outcome predictions a decision maker is faced with a challenge, namely that only a portion of the information in the environment is predictive of a desired outcome. Here, we highlight across several studies the tendency of individuals to assign credit to outcome-irrelevant task representations. We demonstrate that value is assigned to these representations in a model-free and state-independent manner. We further show the association between these low-level value associations and a more sophisticated model-based system and propose how model-free representations might be regulated according to a model of the environment. Finally, we suggest that a deficit in the regulation of outcome-irrelevant model-free associations might lead to behavioral abnormalities such as compulsive behavior. These findings call for a revision of current reinforcement-learning models which are largely based on state-dependent and outcome-relevant learning.

Disentangling conditional dependencies

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Lee, Michael
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Session:
Reasoning

People draw on event co-occurrences as a foundation for causal and scientific inference, but in which ways can events co-occur, and can dependencies between events be combined to form more complex dependencies? Statistically one can express a dependency between events A and C as P(C|A) != P(C), or P(A|C) != P(A). But how can it be specified further? In the psychology of reasoning, the conditional relation P(C|A) is often thought to become biconditional when people add the converse, P(A|C), or inverse, P(not-C|not-A), or both, with the effects of these additions largely treated as equivalent. But from a coherence based logical perspective it can make a strong difference whether the converse or the inverse is added, and in what way. In particular, the addition can occur by forming the conjunction of two conditionals, or by merely constraining their probabilities to be equal. Here we outline four distinct ways of defining biconditional relationships, and illustrate their differences by how they constrain the conclusion probabilities of six inference types. We present a Bayesian latent-mixture model with which the biconditionals can be dissociated from one another, and discuss implications for the interpretation of empirical findings in the field.

Testing AI models as cognitive models for abstract reasoning development

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Pinier, Christopher
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Session:
Reasoning

Abstract reasoning, the ability to solve large-scale problems by taking away unnecessary details (Clement et al., 2007), is essential for human cognition and behavior. However, there remains a lack of cognitive computational models available to study how abstract reasoning emerges and develops in early childhood. We seek to solve this knowledge gap by testing whether deep learning models can explain the key mechanisms that enable children to develop abstract reasoning. Specifically, we investigated whether the Emergent Symbol Binding Network (ESBN; Webb et al., 2021) would be a suitable model. Higher working memory capacity has been shown to facilitate the development of abstract visual reasoning (AVR) in humans. We explore whether ESBN can simulate AVR developmental phenomena by manipulating its memory architecture and training regime. To test this, we observed ESBN's accuracy as it solved two abstract visual reasoning tasks with decreasing batch size per condition (32, 16, 8, 4). We also used two possible encoders: a random and convolutional encoder. We predicted the convolutional encoder should perform better than the random one, given it has more layers (Seijdel et al., 2020). Initial results do not show support for the ESBN model as a model of abstract visual reasoning development because the simpler, random encoder fared better than the convolutional encoder for all batch sizes. Further research will be performed to identify a suitable candidate model for explaining abstract visual reasoning development.

Measuring Persuasion Without Measuring a Prior Belief: A New Application of Planned Missing Data Techniques

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Session:
Reasoning

Research of advice taking frequently utilizes a Judge Advisor System (JAS) paradigm, in which a judge reports a prior belief, receives advice, and then revises their initial estimate. However, several recent studies have shown that the cognitive process of advice taking depends on whether one explicitly accesses and reports their prior or not. In cases where a judge does not report their prior, posterior belief tends to differ from cases in which they do. In social science, this type of phenomenon, where the mere act of elicitation has a treatment-like effect, is sometimes referred to as "measurement reactivity". However, if we neglect to elicit a judge's prior, we can only study posterior belief—not belief change. Building on past work that found typical JAS response behavior is best represented by a "decline, adopt or compromise" (DAC) dual hurdle model, I show that by treating judges' prior beliefs as missing data, we can use imputation techniques to estimate how their beliefs change without directly eliciting their prior. Across both simulation and empirical studies, I demonstrate the feasibility and effectiveness of this planned missing data imputation method, as well as novel theoretical results regarding how people take advice when their priors are not explicitly accessed. The DAC model still adequately fit a task involving continuous estimates, but not a task involving probability judgment for binary outcomes. The general method of utilizing planned missing data designs also has broad potential applications for addressing measurement reactivity in social science.

Jumping to racial prejudice

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Session:
Reasoning

Jumping to conclusions (JTC) refers to the tendency to reach a conclusion or decision without sufficient evidence to justify it. It has been investigated mostly in people with schizophrenia, but has also been found to correlate with conservative political beliefs and with conspiracist thinking. Taking as a starting point recent reports of racist violence in the United States, two preregistered online experiments investigated whether jumping to conclusions is higher in people with stronger racial prejudice as well as with stronger scores in the related constructs of need for closure, social dominance orientation, nationalism, and rejection of science. In Exp 1, US participants completed the classic beads task with neutral content (e.g. red or blue beads drawn from a jar). In Exp 2, the same participants worked through an adaptation of the beads task to contents relevant to racist and political beliefs (e.g. local or foreign crime suspects drawn from a police department). Overall, we found that racist beliefs, and among the constructs related to racist beliefs in particular need for closure, were associated with higher JTC independently of the task content. The findings are interpreted in relation to Bayesian principles of belief revision and learning. Future research could examine the generalizability of the findings to geographic and cultural contexts outside of the US in which racial prejudice occurs.

An empirical test of the two-high-threshold contrast model

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University of Freiburg

Session:
Signal Detection Theory

A longstanding debate in memory research revolves around the question whether recognition memory judgements are best conceptualized as resulting from the direct comparison of a latent memory signal with a response criterion or through a mediation of memory signals by a small number of latent states. These perspectives have commonly been represented by signal detection theory (SDT) and the two-high-threshold model (2HTM), respectively. Kellen and Klauer (2014) showed that common SDT models and the 2HTM make conflicting predictions in a ranking paradigm and implemented a critical test on that basis; their results were in line with the predictions made by the SDT models and contradicted the 2HTM. However, this conclusion was recently called into question by Malejka and colleagues (2022) who proposed that recognition decisions involving multiple stimuli are based on a contrast mechanism. They argued that if the detection probability for any stimulus in a given set is determined by comparing the memory strength of the stimulus in question with the memory strength of the other stimuli in the set, the 2HTM is able to account for the results of Kellen and Klauer (2014). In order to assess whether a 2HTM that incorporates such a contrast mechanisms is empirically adequate, we directly tested one of its key predictions using a ranking paradigm and found evidence against the model. By contrast, our results align well with the predictions made by SDT. We discuss implications of our results for models of single- and multiple-item recognition memory.

Reconciling signal-detection models of criterion learning with the generalized matching law

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Jäkel, Frank

Session:
Signal Detection Theory

To make decisions that lead to favorable outcomes, animals need to take into account both their perceptual uncertainty as well as uncertainty about the outcome associated with their actions. There is a long tradition of research investigating how the outcome structure of a task affects animals' response behavior. The relation between the two has been described by the matching law and its generalizations for tasks with and without perceptual uncertainty. The influence of perceptual uncertainty on decision behavior is often modeled with signal detection theory, which posits that a decision criterion is placed on an internal evidence axis. Where this criterion is placed and how it is updated based on feedback are open questions. Various criterion learning models have been proposed; however, their steady-state behavior across different experimental conditions is not consistent with the aforementioned laws. Our goal is to integrate these approaches to gain a better understanding of the mechanisms by which reinforcements and perceptual uncertainty act jointly to shape behavior. To do so, we first draw an explicit connection between the research on matching laws and signal detection theory by deriving the criterion position that leads to behavior aligned with those laws. Then we develop a learning model that updates the decision criterion trial by trial to learn this criterion position. Our model fits data from a previous experiment well and generates behavior in simulations that is in line with matching laws for perceptual tasks and similar to the subjects' behavior in the experiment.

Two perspectives on decisions under risk and uncertainty: Modeling discrepancies and their psychological explanations

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Session:
Signal Detection Theory

Understanding and predicting the relevant risky choices of modern life is a key goal of behavioral research. However, how do the choices that researchers focus on align with real-life choices that people make? And what are the psychological underpinnings that might explain any differences between the two perspectives? Using a multi-method approach we compiled two comprehensive inventories totaling 165 risky choices, representative of both research and layperson perspectives. Based on cosine similarities of the choices' semantic embeddings and signal detection theory, we identify which choices the two perspectives have in common and where they diverge, and we map their overlap and discrepancies. Moreover, by leveraging the semantic content of choices, we evaluate their relevance to significant real-world risks, as identified by the World Economic Forum and the Global Burden of Disease study. Finally, to better understand why the choices in the research and layperson perspectives are (dis)similar, we examine the role of seven classes of psychological mechanisms (i.e., motivation, experience, affect, cognitive resources, social influence, contextual constraints, and evaluation of choice attributes) in making these choices using Bayesian mixed effects models. In sum, our approach illustrates how well attuned the status quo in behavioral research is to the actual choices and concerns of people. We thereby aim to refine the focus of future studies both in terms of the choices as well as the psychological mechanisms investigated.

Time-variant payoffs and signal detection theory

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Session:
Signal Detection Theory

"Better safe than sorry" summarises the principle that strong responses to rare events may be appropriate if the outcome is important enough. The calculation of optimal bias in signal detection theory (McMillan & Creelman, 1991) formalises this idea and is often used to explain the evolution of response biases. However, signal detection theory assumes that payoffs are stable over time. Trimmer et al. (2017) showed that when payoffs change across trials, the optimal bias may have the opposite sign compared to the case of invariant payoffs. Here, we show that the same can happen when payoffs change within trials. We argue that such changes over time are plausible for evolutionary scenarios to which signal detection theory has been applied, and that conclusions drawn from signal detection theory are not always valid when the assumption of time-invariant payoffs is violated.

Cognitive processes and judgmental strategies in belief updating

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Session:
Beliefs & Selective Attention

Human beliefs are often assumed to be irrational and belief updating is viewed as suboptimal. For example, Ward Edwards (e.g., 1968/1982) famously found that human probability judgments are conservative. However, Edwards also observed that – under certain conditions – judgments often fail to show this conservative bias. Sommer, Musolino, and Hemmer (2023) proposed a theory of belief which distinguishes belief updating from evidence evaluation. Updating is argued to be approximately Bayesian and inaccessible to consciousness. In contrast, evidence evaluation processes are consciously accessible and may be the true cause of apparently non-Bayesian beliefs, including conservatism. We suggest that the presence of conservatism depends on whether a judgmental task requires updating alone or whether evidence evaluation processes are also necessary. Here we test this hypothesis by presenting participants with two versions of judgment problems adapted from Edwards' work, where participants judge the probability of marbles in urns. We manipulate whether the marbles are shown sequentially (the updating alone condition) or all at once (the evidence evaluation condition). We find a difference in optimality between the two conditions, as well as substantial individual differences. Notably, we find that more participants are optimal in the sequential condition. We implement a mixture model to capture individual judgment strategies. We assume that participants are a mixture of five strategies: Normative updating, conservatism, "stick with the prior", frequentist, or random guessing. We discuss the implications of our results in the context of processes involved in belief.

Inferring Constraints on Attention: An Across Species Analysis

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Session:
Beliefs & Selective Attention

The rule-based and information integration tasks have been a staple across a myriad of experiments in comparative psychology as a means to test for the presence of selective attention through the relative differences in the speed of learning. Specifically, rule-based tasks are generally learned faster relative to information integration tasks for learners who possess selective attention, whereas the two tasks are learned equally quickly for learners who lack selective attention. Although Smith et al (2012) documented RB vs. II performance across four species, less is known about species such as rats who have reportedly expressed selective attention. In addition, we present a new experiment involving a switch from one subtask to another. For example, if learners first perform an RB task in which the rule is associated with Dimension 1, then after the switch learners perform another RB task in which the rule is now associated with Dimension 2. This unique manipulation allows us to detect the presence of selective attention by examining how knowledge is transferred from one phase of the experiment to the next. We report results from this experiment on four species: pigeons, rats, rats with prefrontal cortex lesions, and humans.

Generalizing categorization models as attractor networks yields powerful learning architectures

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Session:
Beliefs & Selective Attention

Categorization often involves the use of episodic memory (Nosofsky, 1986; Turner, 2019), and category learning is thought to involve the hippocampus (Mack, Love, & Preston, 2016). In the hippocampus, memory retrieval can be modeled as pattern completion in an attractor network, a recurrent network that can reconstruct previously-observed patterns through complex, dynamic interactions between nodes (e.g., Rolls, 2007). Attractor networks can also be used to model hippocampal learning of sequential dependencies, such as transitive inference and sequence learning, as well as other forms of learning including reinforcement learning (Whittington et al., 2020). In this work, we show that many models of category learning have a natural completion as a two-layer, discrete-time attractor network (a Dense Associative Memory or Modified Hopfield Network; Krotov & Hopfield, 2021; Ramsauer, 2021). We call this meta-model AuToassociative and HEteroassociative Neural Attention (ATHENA). From this perspective, a wide range of mechanisms proposed to explain categorization, as well as common techniques in machine learning, can be implemented in the same architecture through the use of different input representations, forms of memory competition, and learning mechanisms. Furthermore, when augmented with idealized, brain-inspired connections, models in the ATHENA family exhibit flexible sequence learning. We show through simulations that this ability can be used to achieve accelerated replay of observed sequences, multi-step transitive inferences, and one-shot reinforcement learning. Together, this suggests that category learning models can be implemented as special cases of a domain-general hippocampal learning mechanism, providing a link between cognitive models and complex neural architectures.

Can the queueing model of visual search account for feature search?

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Session:
Beliefs & Selective Attention

The queueing model of visual search (Li, Schlather, & Erdfelder, 2023) was developed for visual search in which attentive processing is necessary for the final decision, as it aims to explain the so-called attentional bottleneck, that is, the allocation of attentional resources when transiting from preattentive processing to the more resource-intensive attentive processing. Although the model's explanatory power was supported by the good model fit to empirical conjunction search and spatial configuration search data on a distributional level, whether it can account for feature search is still open. Feature search is important to understand preattentive proccessing and empirical data of feature search provide incremental information for the examination of the model assumptions. In this presentation, I will explain from a technical perspective why the adaptation of the queueing model of visual search to feature search is not a simple reduction but rather an extension. Then I will introduce different approaches of adaptation, compare their advantages and disadvantages using simulation. Finally, fitting the adapted model to empirical data of feature search will be discussed and compared to the result of fitting to conjunction search data based on the same visual material.

A drift diffusion modeling investigation of altered self-referential social perception in psychosis and bipolar disorder

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Session:
Mental Processes & Health

Individuals with schizophrenia (SZ) and bipolar disorder (BD) show disruptions in self-referential gaze perception—a ubiquitous form of social perception that is related to symptoms and functioning. However, our current mechanistic understanding of these dysfunctions and relationships is non-specific, meaning various explanations could account for existing data. This study used mathematical modeling to identify cognitive processes driving gaze perception abnormalities in SZ and BD and how they relate to cognition, symptoms, and social functioning. We modeled behavior of 28 SZ, 38 BD, and 34 controls (HC) in a self-referential gaze perception task using drift diffusion models parameterized to index: drift rate (evidence accumulation efficiency), drift rate bias (perceptual bias), start point (expectation bias), threshold separation (response caution), and non-decision time (encoding/motor processes). Results revealed that aberrant gaze perception in SZ and BD was driven by less efficient evidence accumulation, drift rate biases predisposing self-referential responses, and greater caution (SZ only). Across SZ and HC, poorer social functioning was related to more self-referentially biased start points. Within SZ, drift rate biases and start point biases were associated with hallucination and delusion severity, respectively. These findings suggest that diminished evidence accumulation and perceptual biases may underlie altered gaze perception in patients and that SZ may engage in compensatory cautiousness, sacrificing RT to preserve accuracy. Moreover, biases at the belief and perceptual levels may relate to symptoms and functioning. This underscores the value of using computational cognitive modeling to achieve a more nuanced understanding of the mechanisms of social perceptual processes, like gaze perception, in the study of complex psychopathology.

Reassessing Violence Severity: A Novel Approach Using Pairwise Choice Questions and Order Constraint Models

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Session:
Mental Processes & Health

Abstract:
In the study of violence severity, existing methodologies often encounter challenges in capturing the multi-attribute and context-dependent nature of violent acts (e.g. slapping, pushing etc.) (Harris et al., 2013). Previous research attempts to establish linear orderings have shown limitations, as they did not take into account the fact that violent acts are inherently complex and exhibit subjective nuances in perceived severity (Osman et al., 2017). Building on prior work, particularly that of Regenwetter et al. (2018), our approach deviates by utilizing pairwise choice questions to assess the instability in the ordering of violent acts and reject the transitivity assumption.

The conventional reliance on linear regression for analyzing ordering or ordinal data has faced increasing scrutiny in recent years (Regenwetter & Cavagnaro, 2019; Liddell & Kruschke, 2018). Critics have raised valid concerns about the limitations of this method in capturing the nuanced and complex nature of ordering data. In response to these challenges, our study draws inspiration from methods, which facilitates the implementation of order constraint models. The pairwise methodology provides a nuanced lens through which to interpret violence severity data. By capturing the inherent instability in orderings, our research contributes to a more comprehensive understanding of violence severity perceptions at the population level. Furthermore, the application of order constraint models through pairwise comparisons offers enhanced inference capabilities, surpassing the limitations of traditional linear regression methods.

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Mapping Cognitive Structures in Depression and Anxiety Using Formal Concept Analysis

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Mirström, Mariam

Session:
Mental Processes & Health

Depression and anxiety significantly impact cognitive processes, necessitating the deployment of advanced analytical tools to understand these intricate alterations. Formal Concept Analysis (FCA), a strong mathematical framework, emerges as a pivotal tool in this endeavor, surpassing conventional methods through its capacity to construct a visual and quantitative map of relationships between cognitive stimuli and psychological responses. This unique feature allows for an unparalleled exploration of cognitive structures underpinning these disorders based on a theoretical model.

Utilizing FCA, we can identify and visualize distinct cognitive architectures associated with depression and anxiety. In depression, FCA analysis might highlight a cognitive framework systematically skewed towards negative self-perception and interpretations of external events, evidenced by groups of interrelated concepts such as diminished self-worth and hopelessness. These clusters are intricately linked with pervasive negative attributes, forming a conceptual framework that visually represents the cognitive landscape of depression as theoretically modeled.

Similarly, in anxiety, FCA reveals a complex network of concepts centered around threat perception and worry, underscored by exaggerated frameworks of risk assessment and avoidance behaviors. This intricate visualization not only deepens comprehension of anxiety's cognitive processes but also pinpoints potential focal points for cognitive-behavioral interventions, as derived from the theoretical analysis.

The application of FCA to the study of depression and anxiety marks a significant contribution to the fields of cognitive psychology and mathematical modeling. By clarifying the distorted cognitive architectures characteristic of these conditions, this research leads the way for developing more precise, customized therapeutic strategies, thereby offering a new perspective that enhances understanding of these pervasive mental health disorders through the lens of theoretical exploration.

Exploring stimulus- and action-value reinforcement learning in Parkinson's disease

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Session:
Mental Processes & Health

In Parkinson's disease (PD), degeneration of the dorsal striatal-substantia nigra pars compacta (SNc) pathways is associated with motor symptoms. However, to a lesser extent cell loss also occurs in the ventral striatal-ventral tegmental area (VTA) dopamine projections which are centrally involved in reward prediction error coding, thus affecting reinforcement learning (RL). Here we asked whether neurodegeneration in SNc and VTA differentially affects action value learning and stimulus value learning. We tested PD patients ON and OFF medication (N=22) as well as healthy age matched controls (N=24) on a novel probabilistic bandit task with a color and an action learning condition. In the color value learning condition, reward probabilities were tied to the color of handles (blue or yellow), irrespective of the action performed (pushing or pulling). Conversely, in the action value learning condition, reward probabilities were associated with the push or pull action, regardless of handle color. We developed an error-correction RL model with a new weighting parameter to assess the relative contributions of color and action values to the learning process. Hierarchical Bayesian inference was then employed to estimate latent parameters at both individual and group levels, allowing inference across medication states and participant groups. Using careful model comparison, we tested the hypothesis that action value learning is more impaired in PD patients OFF medication than color value learning, but restored ON medication.

Nonstationarity of the hemodynamic response function in event-related functional magnetic resonance imaging

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Session:
Neuroscience

In the analysis of event-related functional magnetic resonance imaging (fMRI) data, inference on the brain's reaction to a presented stimulus is done with the help of the hemodynamic response function (HRF). It is common practice to assume that the brain's reaction is stationary, that is, the shape of the HRF corresponding to one type of stimulus does not change over time. However, this is not necessarily true; possible sources of nonstationarity are changes in emotions, stress level or learning effects. In this work we aim at answering the following questions: Can we assume stationarity of the hemodynamic response? If not, how does the HRF's shape change over time? In other words, we investigate if current methods sufficiently account for nonstationarity of the HRF. Subsequently, we present a methodology that allows for variation of the HRF's shape over time. To this end, we employ regression models that allow for time-varying beta coefficients to model the HRF's shape. In contrast to existing methods, we analyze fMRI data of multiple subjects, consider multiple regions in the brain and allow for variation in multiple shape parameters of the HRF. Therefore, the proposed procedure accounts for several sources of multiplicity. The procedure is applied to fMRI data of a categorization learning experiment to investigate changes in the HRF's shape over the course of learning.

Massive generalized additive models of neurophysiological time-series

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Session:
Neuroscience

Using statistical models for the analysis of neurophysiological time-series, such as electroencephalography (EEG) or pupil dilation recordings, is complicated by the fact that these signals change non-linearly over time. Additionally, other experimental continuous variables might have a non-linear effect on the measured signal as well. The analysis is typically further complicated by substantial between-subject and between-trial heterogeneity of these non-linear relationships. Generalized additive models (GAMs) are theoretically well-equipped to address both challenges, allowing the estimation of non-linear functions of predictor variables as well as random effects to account for these sources of heterogeneity. However, in practice it is often computationally intractable to include sufficient random effects, as it is not uncommon for cognitive experiments to involve thousands of trials across participants. Here, we combined and extended recently proposed strategies to reduce memory requirements and matrix infill into a sparse GAM estimation algorithm capable of handling previously impossible (non-linear) random effect structures. This allowed us to compute proper GAM models of pupil dilation data with 1.8 million observations and EEG data with 23 million observations. Fitting these models introduces new challenges for established model comparison strategies, which we investigated with simulation studies. Based on the results we established guidelines on how to identify the optimal model. To further facilitate this model-based analysis approach, we provide an openly available Python package of the algorithm and the investigated model comparison strategies.

Modeling EEG with axon delay times to analyze individual differences in cognition

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Session:
Neuroscience

Electroencephalography (EEG) is a fundamental tool in neuroscience, offering key insights into the complex workings of the brain. This study introduces a global model for EEG analysis based on a stochastic autoregressive framework derived from established models of neural behavior. While it is typically thought that EEG frequency bands emerge from synchronous synaptic activity, the global model of EEG states that delays in axonal propagation across corticocortical and thalamocortical connections significantly contribute to the variance observed in EEG signals. The present model predicts that spectral peaks in scalp-recorded EEG data can be solely attributed to axonal time delays at various distances. The autoregressive models are notable for their linear structure that efficiently captures temporal relationships within EEG signals, highlighting the impact of axonal propagation delays with greater computational efficiency.

The model employs a connectivity atlas to determine the connectivity and distances between various brain regions. Additionally, it incorporates distributions of axonal delays and Event-Related Potentials (ERPs) in response to visual stimuli. The approach allows for an accurate reproduction of EEG power spectra, including both resting-state alpha rhythms and ERP peaks. The findings suggest that axonal delay times and neural connectivity within linear predictive models influence EEG dynamics, offering a method to analyze individual cognitive variations through EEG data. In the future, we aim to apply these models alongside cognitive frameworks to draw inferences about individual variations in neurocognition.

Model selection for parsimonious whole-brain decoders: beyond cross-validation

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Session:
Neuroscience

Predicting mental states from functional Magnetic Resonance Imaging (fMRI) data through whole-brain decoders is becoming increasingly popular. To create interpretable decoders, choosing a level of parsimony that determines which brain signals should be included is necessary. The traditional approach has been to test the predictive performance of decoders with different levels of parsimony on new data through cross-validation. However, as fMRI data is rich in variables, the classic cross-validation (CV) approach often leads to inflated whole-brain decoders that include many random voxels. A classic correction approach is the 1 Standard Error (1SE) rule that accepts the most parsimonious decoder with a performance within 1SE of the best-performing decoder's performance in cross-validation. This approach ensures the choice of a more parsimonious decoder. However, it depends on the outlier-vulnerable metrics of the means from the CV performances and the standard error. To deal with this, we propose a pairwise fold (i.e. subject) comparison between the best-performing decoder from the CV and the more parsimonious decoders. The most parsimonious decoder with an insignificant paired t-test against the best-performing decoder is chosen. We show that the pairwise comparison approach is more outlier resistant than 1SE and excludes irrelevant voxels more reliably than the classic CV approach.

Minds for Mobile Agents: A pedestrian model based on psychological principles

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Session:
Social Cognition: Wisdom Of The Crowd

Many organizational decisions require knowledge of how people move around in space. Consider, for instance, managing a crowd during events, building safe infrastructure for pedestrians, and using behavioral interventions to limit infection risk during epidemics. It is therefore not surprising that engineers have spent considerable effort on capturing pedestrian flow. However, while these models are aimed at capturing human movement, they typically lack the human component and fail to incorporate individual differences in people's walking behavior and the goals that underly this behavior. In this talk, I will present the recently developed Minds for Mobile Agents (M4MA) model as an alternative framework that allows for pedestrians to have their own personality and goals, thus capturing more realistic walking behavior than competitor models. I will furthermore present results of ongoing studies that attempt to validate the M4MA model.

Using cognitive models to debias anchoring effects in wisdom of the crowd aggregation

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Session:
Social Cognition: Wisdom Of The Crowd

The wisdom of the crowd aims to aggregate people's knowledge. One role psychological models can play is debiasing people's expressions of their knowledge. An example involves debiasing estimates people provide that may have been impacted by anchoring effects. Because of anchoring caused by initial comparison, what people estimate is a systematic distortion of what they know. Cognitive models can serve to infer the underlying knowledge from the observed behavior. Aggregating inferred cognitive knowledge can then lead to better group aggregates than can be achieved by statistical aggregation of the estimates. We consider data from a new experiment in which 194 people answered questions like "What year did the first McDonalds franchise open?" and "What year did Ronald Reagan become president?". Some people were asked initial comparison questions involving years much later than the answer, some were asked comparisons involving years much earlier than the answer, and others were not asked any comparison question. We show these manipulations lead to significant anchoring effects, and test the ability of a simple cognitive model of anchoring to debias people's estimates and improve the crowd aggregate.

Distribution Inference and Surface Tracing (DIST): A computational model of ensemble perception

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Session:
Social Cognition: Wisdom Of The Crowd

How do we rapidly perceive a crowd's general direction of movement or the average color of a picture? Ensemble perception is the automatic and rapid extraction of the summary statistical properties of collections of stimuli. Ensemble perception is surprisingly accurate given people's recall for individual stimuli. Despite a large empirical literature on ensemble perception, a comprehensive cognitive model of the process is lacking. Here, building on the efficient coding literature, we develop and explore a model of ensemble perception. In the model, people are assumed to behave as if they first infer a CDF of a set of stimuli using kernel density estimation and then use this inferred CDF to make ensemble judgments. We call this model Distribution Inference and Surface Tracing (DIST).
We show that DIST accurately predicts central tendency estimation in the face of changes in the size, variance, and skewedness of a stimuli set, even when constrained to parameters that are resource-rational. Further results are presented that show how DIST performs when fitted to 12 different datasets. DIST is found to fit equivalently to or better than alternative models of ensemble perception, including recent computational models. We also present experiments that aim to test a novel prediction that DIST makes about ensemble perception behaviour. The results of the experiments are taken as preliminary support for DIST.

Why two heads together are worse than apart: A context-based account of collaborative inhibition in memory search

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Session:
Social Cognition: Wisdom Of The Crowd

Contrary to common intuition, groups of people recalling information together remember less than the same number of individuals recalling alone (i.e., the collaborative inhibition effect). To understand this effect in a free recall task, we build a computational model of collaborative recall in groups, extended from the Context Maintenance and Retrieval (CMR) model which captures how individuals recall information alone (Polyn, Norman, & Kahana, 2009). We propose that in collaborative recall, one not only uses their previous recall as an internal retrieval cue, but also listens to someone else's recall and uses it as an external retrieval cue. Attending to this cue updates the listener's context to be more similar to the context of someone else's recall. Over an existing dataset of individual and collaborative recall in small and large groups (Gates, Suchow, & Griffiths, 2022), we show that our model successfully captures the difference in memory performance between individual recall and collaborative recall across different group sizes from 2 to 16, as well as additional recall patterns such as recency effects and semantic clustering effects. Our model further shows that the contexts of collaborating individuals converge more than the contexts of individuals who recall alone. We discuss contributions of our modeling results in relation to previous accounts of the collaborative inhibition effect.

Testing context effects: How to have your cake and eat it, too

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University of Warwick

Session:
Context Effects

What is "context", and how can we best test for its influence (or the lack thereof)? A principled theoretical approach requires a unity between the verbal definition, the mathematical structure implied by it, and the empirical data observed in experimental investigations. The diversity in settings covered by the literature on contextual influences, spanning from low-level foraging tasks in amoeboid organisms to real-world market behavior, goes hand-in-hand with an almost equal diversity of testing approaches designed to assess the presence of context effects. The present work critically evaluates existing approaches to testing context effects and identifies a mismatch between verbal definitions and the mathematical structure. We propose a new approach to testing context effects through the lens of random preference models. We show that conclusions drawn from random preference models coincide with existing context-effect definitions in the experimental designs typically used. However, the ability of those designs to detect context effects is very limited. We demonstrate how testability can be established by linking individual choices across different contexts, providing a general-purpose, sensitive, and specific test of context effects. A reanalysis of existing datasets confirms that context effects occur more frequently than traditional approaches suggest, and that there is a large degree of heterogeneity in which context effects occur, often incompatible with commonly used labels such as "attraction effect". The present work highlights the need for theoretical clarifications related to context effects and establishes a modeling framework that is able to achieve testability for a large class of models.

The disjunction effect does not violate the Law of Total Probability

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Session:
Context Effects

The disjunction effect is defined as an empirical violation of the Sure-Thing Principle, which states that if a person is willing to take an action independently of the outcome of some event, then they must be willing to do so even when the outcome of the event is unknown. A large recent literature has claimed that a probabilistic version of this statement follows from the Law of Total Probability and used this to claim that a number of empirical findings are incompatible with classical decision theory. We show here that this probabilistic approach cannot show violation either of the Law of Total Probability or of any classical decision theory prediction. We derive from first principles an alternative probabilistic relation which is both necessary and sufficient for a disjunction effect to be inferable in between-subject experiments, and we show that many past claims of a disjunction effect are unsubstantiated.

Testing the Additively Separable Representation of Utility Theories: An Experiment Evaluating Monotonicity, Transitivity, and Double Cancellation

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Session:
Context Effects

Additive conjoint measurement (ACM) is a formal theory of measurement that specifies how two variables relate to a third (Debreu, 1960; Luce & Tukey, 1964). ACM plays a foundational role in many utility-based decision theories such as prospect theory (Kahneman & Tversky, 1979). We report the results of a decision making under risk/ambiguity experiment designed to test three axioms necessary for an ACM representation of utility: (1) Monotonicity, (2) transitivity, and (3) double cancellation. Our experiment was designed to induce violations of (1) and (2) via the ambiguity aversion effect. For nearly all participants, we find strong evidence that all three ACM axioms hold, even when participants show ambiguity aversion in their preferences.

Compressed Representations and Attentional Competition in Numeric Integration for Average Estimations

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Session:
Numeric Cognition

The ability to estimate the average value of a number stream is a fundamental aspect of information processing and a building block of value-based decisions. Yet, research on average estimation has focused on the integration of numerical information from a single source. Here, we examined the estimation of averages when competing sources of information are presented. We tested two theories of numeric value integration: the Compressed Mental Number Line (CMNL) predicts underestimation of averages independent of competing information; Selective Integration (SI) predicts that competing information interferes with the target information. Across three experiments, we found a significant underestimation of the averages, and a limited impact of competing information on estimation. Computational modeling shows that the CMNL (together with an explicit noise theory) provides the overall better account than SI to describe estimation behavior in our data. However, about one third of our participants were best described by SI. Among these participants, the computational mechanism of SI consisted of an underweighting of lower numbers in local sample comparisons. Overall, our findings clarify the role of competing information in average estimations, and shed light on the exact cognitive process and limitations of SI as a general theory of sequential information integration.

Characterizing People's Sampling Engines Using Random Generation

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Session:
Numeric Cognition

In random generation tasks, participants generate items such as numbers unpredictably. Recently, we have proposed that, when doing these tasks, people employ their general ability to generate samples for inference; an approach resembling Markov Chain Monte Carlo (MCMC) algorithms in computer science (Castillo et al., 2024). Consistent with this model, we have also found that people's random samples approximate the ground-truth distribution well, which has led us to propose random generation as a technique to elicit people's beliefs (León-Villagrá et al., 2022). Several manipulations have previously been found to affect how random people can be. Here we explore two such manipulations and connect changes in people's behaviour to changes in model parameters. In two experiments, we ask participants to generate samples from two naturalistic domains (lifespans and heights) and manipulate either the speed of production or the requirement to produce the samples randomly (within-participants design).
Consistent with previous research (Towse, 1998), we find that people are less random when the production speed is higher. We find that this difference is characterized quite well by the same MCMC algorithm reporting every second sample in the slower condition. Perhaps surprisingly we find little difference in people's samples when items only need to be reported as they "come to mind", with items being closer together but other typical deviations from randomness not changing.
We use these results to characterize people's sampling engines, finding which aspects of their sampling people can alter when the task changes, and which they cannot.

Investigating the cognitive processes underlying quantitative judgments: Insights from combining cognitive modeling and eye tracking

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Session:
Numeric Cognition

This work investigates the cognitive processes underlying quantitative judgments from multiple cues by combining cognitive modeling with eye tracking. People can judge an object's criterion value based on the object's similarity to previously experienced exemplars (similarity-based process) or by integrating across the object's cues like a linear regression (rule-based process). We test whether people who rely more on the similarity to exemplars as indicated by cognitive modeling also look more at the locations on the screen where the exemplars were shown. To this end, we conducted two eye tracking studies, in which the cues predicted the criterion in an additive (N = 19) or multiplicative (N = 49) way. Participants first learned the criterion value and screen location of each of four exemplars; then, they judged the criterion value of new, briefly presented test stimuli without feedback. Eye tracking measured participants' gaze proportions to the now blank exemplar locations (looking-at-nothing), and cognitive modeling using the RulEx-J framework modeled their reliance on a similarity- over a rule-based process. We found more similarity usage and more looking-at-nothing in the multiplicative study than in the additive study. Focusing on the multiplicative study, participants relying more on the similarity to exemplars also looked more at the blank exemplar locations ($r = 0.36$, $p = .01$). Furthermore, the looking-at-nothing was usually directed at a single exemplar that was similar to the test stimulus. These results show that combining model-based and process-tracing analyses can provide mutually supportive and complementary insights into the cognitive processes underlying quantitative judgments.

A comparison of static models of perceptual confidence and metacognition

Rausch, Manuel
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Session:
Symposium: Computational Models Of Confidence And Metacognition

Recent years have seen a substantial proliferation of static models of confidence and metacognition. The most widely used model, although mostly implicitly assumed by metacognition researchers without empirical testing, is the Independent Truncated Gaussian model (ITG). ITG is the basis of the popular meta-d'/d' method used to quantify metacognitive ability. However, previous modelling studies of perceptual confidence have not included ITG in formal model comparisons. The present study compares model fit of ITG to seven different alternative models of confidence and metacognition all derived from signal detection theory in a reanalysis of four previously published experiments and one new experiment, (i) a masked orientation discrimination task, (ii) a random-dot motion discrimination task, (iii) a low contrast orientation discrimination task, (iv) a dot numerosity discrimination task, and (v) a low contrast number discrimination task. I show that in all five experiments, alternative models provide a better fit than ITG: In the dot numerosity discrimination task, the best fit is achieved by the signal detection rating model. In the other four experiments, the best fit is achieved by either the weighted evidence and visibility model or the logistic weighted evidence and visibility model, implying that at least two sources of evidence are required to account for perceptual confidence, one related to the discrimination judgment, and one related to the reliability of the perceptual evidence. I discuss implications for the measurement of metacognition.

Decision versus non-decision time

Bompas, Aline
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Session:
Evidence Accumulation: General

Decision models typically assume that reaction time on each trial is the sum of decision and non-decision time, the latter being widely held to capture sensory and motor delays. However, the mathematical assumptions allowing this split can be simplistic, arbitrary and lead to counter-intuitive results. How reaction time should be split between decision and non-decision time is both a theoretical and an empirical question. In this talk, I will explore the boundaries between sensory and decision processes, and between decision and motor processes, to propose a biological definition of when decision time may start and stop. I will then present a model-free empirical approach to estimating non-decision time, directly observable in behavioural data. In contrast to non-decision time parameters from model fits, measures extracted using this approach consistently satisfy widespread selective influence assumptions: they vary predictably with visual and motor factors, and do not vary with higher-level task-demands. Last, using the EZ, DDM and LBA models, we conclude that non-decision time parameter from these models is unlikely to consistently reflect visuomotor delays.

Evidence accumulation in continuous response paradigm: General investigation and optimality conditions

Qarehdaghi, Hasan
Shahid Beheshti University

Amani Rad, Jamal
Shahid Beheshti University

Session:
Evidence Accumulation: General

Evidence accumulation refers to a class of cognitive theories for scenarios where a stream of relevant information must be integrated in real time to reach a decision. The optimal solution for this is Bayesian inference, capable of online updating of decision variables based on each new piece of information. In the case of two-choice decisions, Bayesian inference is equivalent to the celebrated theory of evidence accumulation, called the diffusion decision model. Nevertheless, in the case of a continuum of possible decision alternatives, the counterpart of Bayesian inference in the evidence accumulation theories is not developed. We examine the general models of evidence accumulation for continuous decisions and investigate the conditions under which the models perform Bayes optimal inference.

Evidence accumulation is not essential for generating intertemporal preference

Dai, Junyi
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Session:
Evidence Accumulation: General

Traditional models of intertemporal preference tend to be static and thus lack an explicit account of the underlying cognitive processes. Several dynamic models of intertemporal choice have been proposed to address this drawback. Most of such models (e.g., Dai & Busemeyer, 2014; Rodriguez et al., 2014) adopt an evidence-accumulation approach and can account for major behavioral regularities regarding both choice responses and corresponding response times. Recently, Dai et al. (2018) proposed an alternative, non-accumulative framework for modeling intertemporal choice using two time-honored concepts in economics and psychophysics, that is, random utility and discrimination threshold. According to this framework, an intertemporal choice is made upon a large enough random evaluation of the relative advantage of one option over the other. When such an evaluation is relatively small in absolute value, another random evaluation will be made without accumulating any information or evidence from previous evaluations. Such models have been shown to be capable of not only qualitatively accounting for major behavioral effects regarding choice responses and response times but also generally outperforming models built upon the DFT framework. More recent development of such models (Zhang et al., 2023) further revealed their power to accommodate intertemporal preferences measured by matching tasks. The general success of such non-accumulative models suggests that evidence accumulation might not be essential for generating intertemporal preference. Further research is in need for a more rigorous test of this novel framework against other preferential decisions.

Sequential Sampling Models, Underreaction to Rare Extreme Events and Accumulation from Past Experiences

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Session:
Evidence Accumulation: General

Numerous papers on cognitive psychology try to clarify how people solve sequential sampling tasks. These studies have yielded two key findings. One finding suggests that the underlying cognitive processes can be effectively represented by models that assume the summation of noisy evidence toward a decision threshold. A second finding suggests that individuals tend to deviate from optimal choice in the direction of underreaction to rare and extreme events. In the current paper, we show that these two key findings make conflicting predictions when applied to sequential sampling tasks with rare and extreme events. Specifically, while prominent sequential sampling models predict strong overreaction to such events, people tend to underreact. To clarify this apparent inconsistency, we investigate the conditions under which the contrasting predictions emerge, and present a model that incorporates cognitive mechanisms from both streams of research. Our integrated model successfully explains well-established phenomena in sequential sampling tasks and accounts for the unique behavioral patterns associated with rare and extreme outcomes. Taken together, this analysis highlights the value of perspective and methodological integration across theoretical fields. We do so by testing the boundary conditions of existing theories, shedding light on the processes underlying sequential sampling and value based decisions.

An EZ Bayesian hierarchical drift diffusion model for response time and accuracy

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Vandekerckhove, Joachim
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Session:
Evidence Accumulation: General

The EZ-drift diffusion model (EZDDM) consists of an invertible set of equations that relate the drift rate, boundary separation, and nondecision time parameters of the drift diffusion model (DDM) to three summary statistics of choice RT data. The EZDDM is computationally inexpensive, making parameter estimation attainable from simply the accuracy rate and the mean and variance of the correct-trial RTs. We introduce an implementation of the EZDDM within a Bayesian framework, using binomial and normal distributions to model the sampling distributions of these summary statistics. Moving into the realm of Bayesian generative models allows us to implement versatile extensions, such as cognitive latent variable models that capture differences across levels of variation, metaregression structures, and hierarchical models. The resulting "EZ Bayesian hierarchical drift diffusion model" (EZBHDDM) serves as a hyper-efficient proxy model to the hierarchical DDM. We demonstrate, with simulation studies, the efficacy of our proxy model, and present applied illustrations using the graphical Bayesian analysis package JASP. While we find some bias in some of the drift diffusion parameters in recovery studies, we find our proxy model to be robust and highly efficient in recovering critical regression parameters from models that incorporate a metaregression structure. Since the EZBHDDM can be easily implemented in any probabilistic programming language, it can be extended to different Bayesian structures without great computational expense.

Integrating orthographic feature frequency with global matching models of recognition memory

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The University of Melbourne

Osth, Adam Frederick
University of Melbourne

Session:
Memory & Perception

Recent attempts have been made to integrate realistic orthographic representations from the reading literature in global matching models of memory where all orthographic features, namely letters or bigrams were weighted equally. The current study aimed to further extend this equal weight model and explore the consequence of integrating orthographic feature frequency in global matching models of recognition through two approaches. First, we conducted two recognition memory studies where letter or bigram frequency was varied within participants. Results showed feature frequency effects where words comprised of rare letters and bigrams showed higher HR and lower FAR than words comprised of more common letters and bigrams. Orthographic representations (slot coding and bigram models) were situated as individual global matching models where letters/bigrams were either weighted equally or as a linear function of their natural frequency values, and fitted to individual participants' data in a Hierarchical Bayesian framework. Results consistently favoured the feature frequency models over the equal weight models. Second, equal weight and feature frequency global matching models were fitted to a large recognition memory dataset on the level of individual trials to compare their ability in capturing item-level memorability variations across individual words. Model selection results supported the feature frequency model and showed that weighting features by their distinctiveness improved the models ability to capture variability in hit rates across individual words.

A neural network model of free recall and its connection to neural machine translation

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Zhang, Qiong
Rutgers University, New Brunswick

Session:
Memory & Perception

In this work, we propose a neural network model for free recall that draws direct parallels between neural machine translation (NMT) and cognitive models of memory search, specifically the Context Maintenance and Retrieval (CMR) model. We hypothesize that NMT advancements such as attention mechanisms (Luong et al., 2015) closely resemble how humans reactivate prior contexts ("mental time travel"; Tulving, 1985). To demonstrate these parallels, we train a seq2seq model as a cognitive model of memory search, and evaluate behavior against available human free recall data. We find that at intermediate levels of training, the model can capture several phenomena observed in human free recall experiments (Kahana et al., 2022); and after optimization, the model demonstrates the same optimal behavior as previously derived by the CMR model (Zhang, Griffiths, & Norman, 2023). Performing an ablation study, we demonstrate that behavioral differences between models with and without attention aligns with impaired behavior observed in hippocampal amnesia patients (Palombo, Di Lascio, Howard, & Verfaellie, 2019).

Mental Sampling in Preferential Choice: Specifying the Sampling Algorithm

Recent theories of decision making have explained this behaviour using mental sampling mechanisms where people imagine possible outcomes from the available options to guide their choices. Simultaneously, work in other domains has found evidence of particular mental sampling patterns, such as autocorrelations between samples and moderation by prior assumptions, which current decision making theories do not generally consider. Here, we seek to unify this work, developing a new sampling model of preferential choice incorporating these findings in other domains. Our model, based on the Autocorrelated Bayesian Sampler, predicts choice, reaction time, confidence and valuation from a common underlying sampling process. We find a strong correspondence between our model's predictions and empirical choice data, though performance remains below leading explanations for such tasks. Our model does however cover a broader set of response types than existing theories, suggesting the advantages of considering of a wider range of behaviours than are commonly examined in current decision making studies.

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Session:
Memory & Perception

Comparison of Markov and quantum walk models of bistable perception

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Session:
Memory & Perception

Bistable perception is a fascinating psychological phenomenon in which the conscious perception that a person experiences for a single image spontaneously changes across time. In our experiment, twelve participants observed a dynamic display of moving dots, which initially appeared to rotate in one direction before seemingly reversing. The study consisted of six sessions, during which participants observed sequences of these moving dots across five one-minute blocks. They were instructed to report any perceived changes in the rotation's direction – specifying shifts to the left, to the right, or expressing uncertainty. Each report of perceived directional change, along with the time taken to notice such changes, was recorded. This process yielded a detailed dataset of response patterns and the timing of perceptual switches. We developed two models to account for the results: a quantum walk versus a Markov random walk model, both with reflecting bounds and measurement operators designed to detect the three responses. Both models required fitting 6 parameters to each session (5 minutes of viewing) using maximum likelihood methods, and then we computed a G^2 lack of fit measure for each model, person, and session. The results, averaged across the 6 sessions for each participant, indicated that the quantum model produced a better fit for 9 out of the 12 participants as compared to the Markov model; however, the advantage was small.

Tactile sensorimotor transformations are reliable over time, but do not generalise across tasks

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Kayser, Christoph

Heed, Tobias
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Session:
Memory & Perception

Locating incoming sensory information is an essential element of sensorimotor transformations. In tactile localisation, conflicting information from different reference frames can cause judgment errors and slow processing. For example, people are faster and more accurate in locating stimuli delivered to uncrossed compared to crossed arms, presumably because the crossed posture involves conflicting information between the anatomical ("which side of my body") and external ("which side of the room") spatial information. The difference in performance between crossed and uncrossed conditions is known as the 'crossing effect'. In the current study, we examined to what extent tasks with crossing effects are suited for studying individual differences, focusing on: 1) the within-subject reliability of crossing effects for individual tasks, and 2) the generalisation of crossing effects across different tasks. Ninety-one participants completed three tactile perception tasks that involved uncrossed and crossed limb postures. Two weeks later, they returned to the lab to complete the same three tasks again. Two of the three tasks exhibited good within-subject reliability for both reaction time and accuracy, as evidenced by high intra-class correlations. However, crossing effects did not correlate between different tasks, even though processing speed did. These findings indicate that cognitive processes may generalise poorly across tasks even when they show within-subject reliability over time.

Teaching functions with Gaussian processes

Malaviya, Maya
New York University

Ho, Mark

Session:
Social Cognition

Humans are remarkably adaptive instructors who can adjust advice on complex tasks based on a learner's current knowledge and goals. However, paradigms in cognitive psychology generally examine pedagogy in constrained and discrete tasks, like categorization or feature learning, with a small set of actions for the instructor to choose from. We examine teaching in continuous domains, where there are theoretically infinite choices, and model how teachers formulate a computationally tractable Bayesian inference about which choice is best. We propose that teachers can reason about learners as agents that update their hypotheses using Gaussian process regression. We tested this in a visual function completion task, in which an agent observes dots placed along a 2D plane and must draw a line that represents the underlying function that produced those dots. We modeled how a teacher, who knows the underlying function, would select points that best help a learner recover the function. Preliminary evidence suggests teachers are sensitive to learners' priors about continuous functions. For instance, when learners expect a diverse range of function types (linear, quadratic, periodic, etc.) then teachers tend to select examples that help distinguish between those types. Conversely, teachers did not adhere to this pattern if learners saw just one function type. Ongoing analyses will compare human data to a model-based teacher agent that reasons about the learner's Gaussian process regression to evaluate the utility of showing certain points. Our results provide insight into how teachers formulate pedagogical guidance in computationally tractable ways, even in complex, continuous domains.

State of play: Interacting latent Markov chains in repeated games

Speekenbrink, Maarten
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Session:
Social Cognition

Repeated games provide a controlled yet rich framework for studying social interactions. Classic game-theoretic analyses focus on determining equilibrium solutions for completely self-interested, fully informed, and rational agents. Other, arguably more valid approaches, tend to focus on agents with socially-oriented utility functions, or with less-than perfect planning-ahead capabilities. Here, I will present the framework of interacting latent Markov chains in repeated games, leveraging the strengths of both approaches. I will assume that at each decision point, a player's actions are determined by their discrete latent state, which may depend on learned beliefs about the strategies of other players, yet also on the social orientation towards other players (e.g. love, hate, ignorance). Players can transition between such states as a consequence of the actions of all players. I will show the unique advantages of this framework, and contrast it to other common approaches to repeated games, including traditional solutions such as subgame perfect Nash equilibria and Markov perfect equilibria.

Exploring the social and temporal dynamics of striving for cognitive consistency in political belief change

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Center for Environmental Systems Research

Session:
Social Cognition

How does striving for cognitive consistency affect political polarization? The psychological consistency theories have found large support in empirical research, yet, the temporal, social, and political consequences of individuals striving for cognitive consistency are little understood. In the present work, an agent-based model simulating change in individuals' political beliefs was developed, based on the basic assumption that people strive for cognitive consistency in their political beliefs. While it can be assumed that all people strive for cognitive consistency, research has also shown the understanding of what consistency means for an individual differs. Hence, people differ in their cognitive models. In the present work, a cognitive model is formalized as a correlation matrix that indicates how strongly different beliefs should relate to each other. To derive different cognitive models, correlational class analysis is used on the European Social Survey data. In the agent-based simulation, agents can interact with each other and change their beliefs towards more consistency. Simulation results are analyzed regarding political polarization/consensus, showing that striving for consistency increases polarization, leads to more extreme beliefs, yet is also necessary to maintain diversity in beliefs. Differences in cognitive models amplify these effects. Limitations and different design choices are discussed. Although the macro-level results of the simulation are difficult to validate, it is argued for the value of testing cognitive psychological theory and its consequences in the temporal and social interplay.

Theoretical implications of how we model night gaps in ESM

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Utrecht University

Session:
Symposium: Advancing Dynamic Models of Psychological Processes

Night gaps are inherent to experience sampling method (ESM) data, yet they are often overlooked or approached solely as a dynamic modeling problem rather than an avenue of research. As a result, the theoretical implications of current solutions are typically not (fully) considered or discussed. These solutions involve (1) ignoring the night gap by considering the night interval as a regular interval, (2) removing the night gap by not regressing the first measurement of the day on the last measurement of the previous day, or (3) treating the night gap as a missing data problem.
In this presentation, I propose an alternative method that estimates the relation between the first observation of the day and the last observation of the previous day freely, as a separate parameter. Additionally, I make explicit for each of these methods their theoretical implication for the process of interest within the context of the fundamental first-order autoregressive (AR[1]) model. Since the current methods are special cases of the proposed alternative, we can test which method best describes the process of interest. Through an empirical N=1 example of various ESM variables, I demonstrate that the best-fitting method differs per variable. This implies that some processes may exhibit different dynamics during the night than during the daytime, providing a stepping stone to understanding and modeling night gaps in ESM.

A multiverse analysis of the psychometric properties and robustness of dynamic structural equation models

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Steinhilber, Meike
University of Mainz

Session:
Symposium: Advancing Dynamic Models of Psychological Processes

Although research investigating the dynamics of complex systems is a mainstay in fields such as epidemiology, economics, and certain sub-disciplines of psychology, such investigations are increasingly gaining traction in cognitive psychology. This surge in interest is largely attributed to the emergence of Dynamic Structural Equation Models (DSEMs). DSEM represents a powerful statistical tool for modeling longitudinal data, integrating elements of time-series analysis, multilevel modeling, and structural equation modeling. The availability of DSEM is increasingly broadened due to its translation into free software platforms like R and Stan. However, before embracing DSEM on a larger scale, it is crucial to thoroughly investigate its psychometric properties and parameter estimation capabilities. In this context, our study embarks on an exploration of a multiverse of methodological options related to DSEM application. Specifically, we examine the impacts of varying sample sizes, number of timepoints, priors, and sampler settings—including the number of iterations, seeds, and initial start values—on the robustness and reliability of the model outcomes. This comprehensive analysis aims to provide deeper insights into the optimal use of DSEM in cognitive psychological research, paving the way for their more informed and effective application in the field.

Capturing asymmetrical temporal dynamics using thresholded time series models

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Donders Institute for Brain, Cognition and Behaviour

Session:
Symposium: Advancing Dynamic Models of Psychological Processes

Commonly used time series models are able to capture temporal dynamics of psychological processes over time. However, these models assume that the temporal dynamics function similarly regardless of the current value of the time series. We argue that many psychological processes likely involve asymmetrical temporal dynamics, for example, that the effect of more-than-usual sleep (for a given person) on wellbeing is different from that of less-than-usual sleep. We illustrate how overlooking asymmetrical dynamics can adversely impact inferences one draws, for example, of the effect of sleep on wellbeing. We demonstrate how we can adapt commonly any time series model to allow for asymmetrical dynamics in, and how doing so improves model fit and inferences.

You Could do Better Tomorrow - Modeling day to day fluctuations in cognitive performance

Aristodemou, Michael
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Session:
Symposium: Advancing Dynamic Models of Psychological Processes

Interest in psychological dynamics can span multiple timescales, ranging from fast fluctuations at a resolution of seconds, to occasions (morning, afternoon, evening), days, and even months. However, currently available implementations of DSEM are restricted to two-levels forcing researchers to opt for suboptimal choices, either ignoring some timescales or building models using multi-step approaches with known psychometric pitfalls (e.g. loss of uncertainty in estimates). By leveraging the flexibility offered by the probabilistic programming language Stan we can extend DSEM to allow for the contemporaneous modeling of processes across multiple timescales. We showcase this modeling innovation in a rich dataset (VEKTOR) tracking children's cognitive training progress. We show that children's cognitive performance can fluctuate over the span of seconds and days using a 3-level DSEM. Researchers can easily extend this parameterization of DSEM to specify a hierarchical DSEM with their desired number of levels.

A state-based time series model capturing mood fluctuations over time

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Session:
Symposium: Advancing Dynamic Models of Psychological Processes

Time series models are increasingly used to investigate fluctuations in psychological processes over time. Advanced time series models such as Dynamic Structural Equation Models have proven a powerful tool to capture, for example, mood fluctuations and to subsequently inform diagnosis and treatment. Arguably, temporal dynamics of mood are not gradual but involve states, especially in clinical populations. Therefore, we propose an extended time series model in which we implement states and allow temporal dynamics parameters to vary across these states. We show how these models outperform stateless models in capturing mood fluctuations and how model parameters can be used to inform clinical practice.

Using multinomial processing trees to model latent cognitive processes during garden-pathing

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Session:
Symposium: Computational Psycholinguistics

Garden-path sentences such as “While the doctor visited the patient collapsed” are one of the most-studied phenomena in psycholinguistics, as they typically engender large, reliable slowdowns in reading compared to control conditions (“While the doctor visited, . . . ”). These reading slowdowns have classically been interpreted as indexing syntactic reanalysis, that is, switching from an initial incorrect structure (“the doctor visited the patient”) to the correct one. More recently, however, it has been argued that readers do not always carry out reanalysis, but may retain the incorrect structure instead (e.g., Christianson et al., 2001). Furthermore, both the online reading time data and offline sentence judgments (“grammatical”/”ungrammatical”) may be contaminated by trials in which participants are not paying attention to the stimulus at all. Given these potential contaminants, it is important to go beyond simply comparing condition means. Multinomial processing trees, which take observed responses as being generated from a cascade of latent cognitive processes, can be a highly useful tool in this context. I present a model that partitions the processing of the critical sentence region (“collapsed”) into three components: attention, surprise, and reanalysis. Reading times are analyzed as coming from a mixture distribution whose components are identified by the costs of the latent processes that either occur or do not occur in a given experimental trial. The full tree model provides better predictive fit than simpler models, and the estimates suggest that syntactic reanalysis is much more costly than previously assumed once contaminants are taken into account.

Introducing ScanDL: A diffusion-based generative model of eye movements in reading

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Session:
Symposium: Computational Psycholinguistics

Eye movements in reading reveal cognitive processes involved in human language understanding. As such, they have been pivotal in psycholinguistic research. More recently, they have also been utilized for both interpreting and enhancing the cognitive plausibility of language models as well as for inference tasks, such as deducing properties of the reader or the text being read. However, eye movement data is scarce and usually unavailable at inference time, which constitutes an obstacle for this branch of research. Traditional approaches trying to amend this issue relied on cognitive models to generate synthetic scanpaths, but recent shifts favor purely machine-learning-based methods, as they prove more suitable for the sole task of generating human-like synthetic eye movement data. Based on recent research that applies continuous diffusion processes to discrete data, we present ScanDL, a discrete sequence-to-sequence diffusion model that produces human-like scanpaths on texts. The model captures the multi-modal interactions of the input by employing pre-trained word embeddings and a joint representation of the text and the fixations in space. Our assessment of ScanDL across different settings demonstrates its superior performance against previous benchmarks in scanpath generation. Moreover, an extensive psycholinguistic analysis reveals that ScanDL captures key phenomena observed in human readers, such as surprisal, word length, and frequency. We underline the model's ability to exhibit human-like reading behavior and further show that it can be used for power analyses, and could, prospectively, also be used for piloting psycholinguistic experiments.

Modeling individual differences in a pragmatic reference game as a consequence of variable disengagement from unsuccessful strategies

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Session:
Symposium: Computational Psycholinguistics

Individuals are known to vary in their likelihood of drawing Gricean pragmatic inferences. We present the first algorithmic-level model of a pragmatic reasoning task, in ACT-R, to formalize the way in which this variability could come from individual differences in domain-general cognitive variables.
In non-linguistic reference games (RefGames), participants select a referent for a possibly-ambiguous message. RefGame participants vary in their tendency to derive "simple" and "complex" Gricean inferences (Franke & Degen, 2016).
Mayn & Demberg (2022) found that more complex RefGame inferencing was strongly associated with successful problem-solving in Raven's Progressive Matrices (RPM). One shared mechanism which may underlie successful RPM and RefGame performance is the ability to use internal negative feedback to efficiently disengage from unsuccessful strategies: Stocco and colleagues' (2021) ACT-R model captures an observed relationship between one's negative feedback strength (Fneg) and RPM success.
Based on the Stocco model, we present an ACT-R model of RefGame where success requires disengaging from strategies which fail to provide a high-quality (unique) answer. Our model stochastically applies interpretive strategies of varying complexity until arriving at a unique answer or else guesses after a timeout corresponding to individual persistence. Deriving complex inferences ultimately requires faster disengagement via stronger Fneg (or higher persistence).
Our model generates several novel predictions: (a) RefGame performance should correlate with specific Fneg and persistence metrics, (b) more complex trials will take longer to solve, (c) incorrect responses will have shorter response times and (d) correct responses will more often demonstrate eye movements predicted for complex strategy execution.

Interindividual differences in predicting words versus sentence meaning: Explaining N400 amplitudes using large-scale neural network models

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Session:
Symposium: Computational Psycholinguistics

Prediction error, both at the level of sentence meaning and at the level of the next presented word, has been shown to successfully account for N400 amplitudes. Here we address the question of whether people differ in the representational level at which they implicitly predict upcoming language. To this end, we computed a measure of prediction error at the level of sentence meaning (magnitude of change in hidden layer activation, termed semantic update, in a neural network model of sentence comprehension, the Sentence Gestalt model) and a measure of prediction error at the level of the next word (surprisal from a next word prediction language model). When using both measures to predict N400 amplitudes during the reading of naturalistic texts, results showed that both measures significantly accounted for N400 amplitudes even when the other measure was controlled for. Most important for current purposes, both effects were significantly negatively correlated such that people with a reversed or weak surprisal effect showed the strongest influence of semantic update on N400 amplitudes. Moreover, random-effects model comparison showed that individuals differ in whether their N400 amplitudes are driven by semantic update only, by surprisal only, or by both, and that the most common model in the population was either semantic update or the combined model but not the pure surprisal model. The current approach of combining large-scale models implementing different theoretical accounts with advanced model comparison techniques enables fine-grained investigations into the computational processes underlying N400 amplitudes, including interindividual differences in the involved computations.

Neural language model gradient as a predictor of ERPs and sentence acceptability

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Session:
Symposium: Computational Psycholinguistics

Fitz & Chang (2019) argue that event-related brain potentials (ERPs) during sentence comprehension result from detection and incorporation of word-prediction error. The N400 component would correlate with prediction error while the P600 would be indicative of error backpropagation in the language system. Psycholinguistically speaking, the latter is an estimate of how much the comprehended sentence changes the reader's language knowledge. Fitz & Chang evaluate their theory using (backpropagated) prediction error from a neural network trained on an artificial miniature language, and show that it indeed accounts for many ERP effects from the literature.

I present an evaluation of Fitz & Chang's (2019) account on a corpus of EEG data recorded from participants reading naturalistic English sentences (Frank et al., 2015). At each word of the sentences, surprisal and the total gradient of recurrent-layer connections were estimated by an LSTM language model trained on a large, natural language corpus. Consistent with the theory, higher surprisal resulted in stronger N400 while higher gradient resulted in stronger P600, although a detailed analysis of the ERP time course suggests the apparent P600 effect should be interpreted as a reversed N400 effect.

The same model was then applied to over 4000 sentences from a large-scale sentence acceptability rating study (Lau et al., 2017). Higher gradient was associated with lower acceptability (over and above surprisal), suggesting that lower subjective acceptability is partly due to larger update in language knowledge, and not only to lower sentence probability.

Scan Pattern Similarity Predicts the Semantic Similarity of Sentences Across Languages Above and Beyond Their Syntactic Structure

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Session:
Symposium: Computational Psycholinguistics

Human cognition is a highly integrated system which synchronizes processes and representations across modalities. Previous research on the synchronization between attention and sentence production demonstrated that similar scene descriptions correspond to similar sequences of attended objects (scan patterns). Here, we generalise this finding from English to languages with different word order. We test whether synchronicity holds not just within a language but across languages and examine the relative contribution of syntax and semantics. 74 participants (24 English, 28 Portuguese, 20 Japanese) described objects (N = 24), either animate (e.g., man) or inanimate (e.g., suitcase), situated in a visual scene, while being eye-tracked. Across all participants, pairwise sentence similarity was computed using Universal Sentence Encoder, which generates multilingual vector-based meaning representations. Part-of-Speech (POS) sequences, shallow representation of the syntax of sentences, were extracted using spaCy. Similarities between POS sequences and scan patterns were measured using Longest Common Subsequence. We found that similar sentences are associated with similar scan patterns in all three languages. Moreover, we demonstrated for the first time that this relationship holds across languages (e.g., if a Japanese and a Portuguese sentence are semantically similar, their associated scan patterns are also similar). In contrast, we find that syntactic (POS) similarity is predicted by scan patterns only within the same scene and only between languages with similar word order. This confirms that visual attention and language production are synchronized, but also points to a grammar of perception that is language-independent, goes beyond syntactic realizations, and manifests as oculomotor responses.

Meaning modulations and stability in Large Language Models: An analysis of BERT embeddings for psycholinguistic research

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Session:
Symposium: Computational Psycholinguistics

Computational models of semantic representations have long assumed a single static representa-tion for each word type, ignoring the influence of linguistic context. Recent Large Language Models (LLMs), however, learn token-level contextualized representations, allowing the study of how semantic representations change in context.
We use BERT to probe type- and token-level representations for their ability to i) ex-plain semantic effects for isolated words (semantic relatedness and similarity ratings, lexical decision, and semantic priming), ii) exhibit systematic interactions between lexical semantics and context, and iii) explain meaning modulations in context.
Across several empirical studies, we show that BERT representations satisfy two desid-erata for psychologically valid semantic representations. First, they have a stable semantic core which allows people to interpret words in isolation and prevents them to be used arbitrarily. Neighborhood density of prototype embeddings explains unique variance in lexical decisions, target-prime relatedness accounts for reaction times in primed lexical decision, and geometric proximity in BERT's representational space accounts well for both semantic similarity and relat-edness. Second, BERT representations interact with sentence context in systematic ways, with representations shifting as a function of their semantic core and the context: replacing word A for word B makes B's representation shift away from its prototype representation and closer to that of A, and the closer A and B's prototypes are, the easier it is for the model to effectively contextualize the replacement. Finally, we show that BERT representations can capture meaning modulations across and within word senses: for example, the representation for tomato is clos-er to that of green in the sentence The tomato in my garden is ripening and to that of spaghetti in the sentence You can still see some tomato pieces in the pasta sauce, despite the referent possibly being the same.
Therefore, a single, comprehensive model which simultaneously learns abstract, type-level prototype representations as well as mechanisms of how these interact with context can explain both isolated word effects and context-dependent variations. Notably, these variations are not limited to discrete word senses, eschewing a strict dichotomy between exemplar and prototype models and re-framing traditional notions of polysemy.

Retrieval (N400) and Integration (P600) in language comprehension

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Session:
Symposium: Computational Psycholinguistics

Neurocognitive models of language comprehension are informed by the differential modulation patterns of the N400 and P600 components of the Event-Related Potential (ERP) signal during incremental language comprehension. Models differ, however, in the functional interpretation assigned to the N400 and P600, leading to fundamentally different comprehension architectures that yield different predictions regarding the modulation of these components. Here, we focus on the predictions of an explicit neurocomputational model that instantiates Retrieval-Integration (RI) theory. On RI theory, N400 amplitude reflects the contextualized retrieval of word meaning from long-term memory, and P600 amplitude indexes the integration of retrieved word meaning into the unfolding utterance representation. In particular, RI theory predicts that the well-known N400-effect for semantic incongruity can be wiped out completely when the retrieval of word meaning is facilitated through lexical and contextual priming, and moreover, that the integrative processes underlying the P600 are graded for plausibility, such that P600 amplitude increases as words get less plausible. ERP evidence will be discussed that directly confirms these predictions, which are unique to RI theory, thereby critically challenging alternative accounts and models of the N400 and P600.

Studying language and cognition using models of discourse meanings

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Session:
Symposium: Computational Psycholinguistics

One of the challenges in cognitive research on language is to find meaning representations that would go beyond simple (lexical) representations and be able to capture the incremental interpretation of discourse. At the same time, the representations should be practical enough to be deployable on data that are of interests to cognitive scientists.
In this presentation, I discuss a way to make use of meaning representations developed in formal discourse semantics, Discourse Representations Structures, to advance our understanding of how interpretation and behavioral measures (reading data) are related. I will present a text corpus with eye-tracking and self-paced reading data that was fully annotated with Discourse Representation Structures. Then I will show how such an annotation can be used to investigate a link between behavioral measures (fixations, reaction times) and discourse meanings. Finally, time permitting, I show how we can use the annotated corpus to test claims regarding meaning and cognition present in theories of sentence processing, e.g., the assumption that processing cost and the introduction of discourse referents are interlinked (Dependency locality theory, Gibson, 1998, among others).

Unveiling the Hidden: Machine Learning Approaches for the Discovery of Latent Structures

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Session:
Symposim: Deep Learning And Simulation-Based Inference For Computational Cognitive Modeling

In social sciences, the transition from verbal theories to computational models presents a significant challenge, primarily due to the difficulty in quantifying complex human behaviors into discrete parameters. Traditional analytical tools, such as Principal Component Analysis (PCA), have long been the preferred method for reducing high dimensional data into low-dimensional spaces. However, these linear approaches often fall short in capturing the intricate relationships that characterize human behavior. This talk introduces a novel application of variational auto-encoders (VAEs) combined with clustering techniques to provide an alternative way to discover and construct latent dimensions for behavioral problems. Unlike PCA, VAEs have the unique advantage of modeling non-linear relationships, thereby providing a deeper, more accurate interpretation of data.

Mainly, our aim is to provide a tool that can distill critical dimensions for specific behavioral problems with an application on experimental data from a novel procrastination task. However, the implications of this research extend beyond individual domains, supporting a broader application. The ability to discern non-linear relationships and hidden structures can thereby enhance understanding and parametrization of various behavioral phenomena, ultimately leading to the development of better predictive models and theoretical frameworks. As such, this talk aims to evaluate machine learning as a tool for exploratory data analysis with an eye toward inspiring richer and more complete psychological theories.

TogetherFlow: Bayesian simulation-based emergent attentional dynamics in room-oriented immersive systems

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Session:
Symposim: Deep Learning And Simulation-Based Inference For Computational Cognitive Modeling

A room-oriented immersive system (ROIS) augments dynamic virtual environments for multiple people to experience in a shared physical space. User movement patterns in ROIS provide context for observing emergent attention with two intersecting challenges. On the one hand, computational modeling of motion-induced attention in virtual environments has privileged single-user, head-centered experiences, leaving out the shared experiences that ROIS provides. On the other hand, while attention modeling has gathered sustained interest in multi-agent simulation, existing simulation environments often use simplified spatial configurations, compromising the agents' perceptual viability in the physical world. To address the challenges above, we introduce TogetherFlow, a modeling framework for distributed and emergent multi-agent spatial attention using Bayesian simulation-based inference. In this framework, we represent agent attention as a spatial probability distribution based on proximity and orientation to the surrounding audiovisual objects in game-based virtual navigation environments. For the forward problem, a cluster analysis of agent attention simulates moment-to-moment attentional distributions along global navigation trajectories using variational Bayes. For the inverse problem, a generative neural network recovers the attentional distribution given the global trajectories, and its performance is extensively validated using principled Bayesian methods. Through a large-scale simulation study of models using different agent representations and movement mechanisms, we observe how cross-modal motion perception influences the emergence of agent attention and how it introduces self-organizing behaviors in ROIS. This observation will further allow us to design adaptive interfaces for augmenting the virtual environments.

Using simulation-based Bayesian inference to explore the unidentified spaces of (neuro-)cognitive models

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Session:
Symposim: Deep Learning And Simulation-Based Inference For Computational Cognitive Modeling

In Bayesian inference, (joint) posterior distributions should always exist for parameters of a model given real priors. In the extreme case, a completely unidentified model, one that does not provide any inference about the data whatsoever, will result in the joint posterior exactly equaling the joint prior. There exist many useful (neuro-)cognitive models in the fields of mathematical psychology and cognitive neuroscience for which only some parameters are unidentifiable while others are identifiable. This is especially true for new models and extensions of existing models. I show from experience in multiple studies why simulation-based Bayesian inference using artificial neural networks is extremely useful for exploring and testing these (un)identified models. I show examples from Drift-Diffusion Models with internal noise, models of stop-signal cognition, and confidence judgments. I show that simulation-based Bayesian inference using the package BayesFlow is often much easier to use for unidentified models than Probabilistic Programming Languages that use MCMC algorithms (e.g. Stan and JAGS). I will show examples of using neural data to make unidentified (neuro-)cognitive models identifiable in order to measure condition- and individual-differences in cognition. Specifically, I will show how the joint posterior space of unidentified cognitive models will shrink towards some meaningful posteriors when neural data is also explained by neuro-cognitive models. I suggest a future in which the unidentifiability of (neuro-)cognitive models is systemically explored with simulation-based Bayesian inference.

Invertible neural networks for simulation-based prior knowledge elicitation

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Session:
Symposim: Deep Learning And Simulation-Based Inference For Computational Cognitive Modeling

A notable characteristic of Bayesian statistics lies in its capability to integrate prior knowledge into the modeling process. While this feature holds substantial potential, its practical implementation is far from straightforward. Expressing prior knowledge involves formulating prior distributions for the model parameters during the modeling process. This requires both the ability to interpret the model parameters and the skill to translate prior knowledge into valid distributions.
In response to this challenge, we suggest a simulation-based prior elicitation method that translates expert knowledge into corresponding priors, regardless of the underlying data-generating model. Depending on the analyst's preference, our method allows for learning parameters of a pre-specified prior distribution family via stochastic gradient descent or a joint prior distribution over all model parameters via normalizing flows that accounts for correlation between model parameters.

Integrating efficient sensitivity analyses into amortized Bayesian workflows

Sensitivity analyses are a useful tool for ensuring the robustness of computational workflows in psychology and beyond. However, they are typically forgone, as they require numerous model refits and become downright infeasible for models where even a single model fit can be computationally expensive. In this talk, we present a framework for efficiently integrating different types of sensitivity analyses into simulation-based inference with deep learning (aka amortized Bayesian inference). Our method enables efficient (i) prior and likelihood sensitivity analysis by training a single neural network for all prior and likelihood configurations of interest, (ii) data sensitivity and multiverse analysis by leveraging the fast inference of trained neural networks, and (iii) model misspecification detection by measuring the agreement within a deep ensemble of neural networks. We present experiments on representative models that underscore the effectiveness of our approach for both parameter estimation and model comparison tasks. Our results suggest that integrating sensitivity analysis into amortized Bayesian workflows is a promising step towards reliable and robust inference.

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Session:
Symposim: Deep Learning And Simulation-Based Inference For Computational Cognitive Modeling

Assessing the robustness of amortized Bayesian inference for evidence-accumulation models applied to different experimental designs

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Session:
Symposim: Deep Learning And Simulation-Based Inference For Computational Cognitive Modeling

Evidence-accumulation models (EAMs) are popular tools for analyzing speeded decisions in two-alternative forced choice tasks because they allow researchers to make inferences about the decision process. Estimating EAM parameters from empirical data can be computationally expensive, especially in a Bayesian framework. To lower this barrier, researchers have proposed to amortize these costs by incorporating deep neural networks (DNNs) into the estimation procedure leading to amortized Bayesian inference (ABI). The DDNs are trained to learn the relationship between model parameters and model simulations to predict faithful posterior distributions for empirical data. Importantly, the DNNs can learn such relationships for variable data sets, model configurations, and other contexts. Previous research has shown that experimental design factors can impact the faithfulness of traditional methods for estimating EAM parameters. While ABI has shown many promising results for EAMs both in simulations and in empirical data, little work has been done on how experimental design factors affect the performance of ABI. By conducting a comprehensive simulation study, we aim to establish a benchmark for the generalizability of different DNN architectures for EAMs across common experimental designs. Moreover, we will assess their generalizability on empirical data by comparing ABI to traditional parameter estimation methods. With our results, we hope to shine a light on the sensitivity of ABI to experimental design factors for EAMs. These insights could be used to further improve current ABI approaches and as a reference for practitioners for designing their experiments.

Amortized Bayesian inference with hybrid expert-in-the-loop and learnable summary statistics

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Session:
Symposim: Deep Learning And Simulation-Based Inference For Computational Cognitive Modeling

Amortized Bayesian inference (ABI), a subset of simulation-based inference (SBI) fueled by neural networks, has rapidly grown in popularity across diverse scientific fields. Summary statistics are an essential dimensionality reduction component of ABI workflows and most methods to-date rely either on hand-crafted (i.e., based on domain expertise) or end-to-end learned summary statistics. In this work, we explore hybrid methods to harness the complementary strengths of both sources. Our first method directly conditions a neural approximator on both types of summary statistics, thereby extending traditional end-to-end approaches in a straightforward way. Our second method employs an auxiliary generative model to learn a latent summary representation that is statistically independent from the expert summaries. We explore various aspects of our hybrid methodology across different experiments and model instances, including active learning, perfect domain expertise and imperfect artificial experts represented by pre-trained neural networks. Our empirical results suggest that hybrid representations can improve parameter estimation and model comparison in settings of scientific interest, warranting the viability of an "expert-in-the-loop" approach. The performance gains are especially promising in scenarios with low to medium simulation budgets.

Validation and comparison of non-stationary cognitive models: A diffusion model application

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Session:
Symposim: Deep Learning And Simulation-Based Inference For Computational Cognitive Modeling

Cognitive processes undergo various fluctuations and transient states across different temporal scales. Superstatistics are emerging as a flexible framework for incorporating such non-stationary dynamics into existing cognitive model classes. In this work, we provide the first experimental validation of superstatistics and formal comparison of four non-stationary diffusion decision models in a specifically designed perceptual decision-making task. Task difficulty and speed-accuracy trade-off were systematically manipulated to induce expected changes in model parameters. To validate our models, we assess whether the inferred parameter trajectories align with the patterns and sequences of the experimental manipulations. To address computational challenges, we present novel deep learning techniques for amortized Bayesian estimation and comparison of models with time-varying parameters. Our findings indicate that transition models incorporating both gradual and abrupt parameter shifts provide the best fit to the empirical data. Moreover, we find that the inferred parameter trajectories closely mirror the sequence of experimental manipulations. Posterior re-simulations further underscore the ability of the models to faithfully reproduce critical data patterns. Accordingly, our results suggest that the inferred non-stationary dynamics may reflect actual changes in the targeted psychological constructs. We argue that our initial experimental validation paves the way for the widespread application of superstatistics in cognitive modeling and beyond.

Modeling the impact of stress on representation formation using variational autoencoders

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Session:
Symposim: Deep Learning And Simulation-Based Inference For Computational Cognitive Modeling

How does stress alter the nature of mental representations, what are the downstream impacts on memory and decision making, and how can this process be captured in detailed computational terms? Despite the prevalence of stress in our daily lives, the impact of stress on memory and its consequences for complex behaviors such as decision-making, are unknown. Moreover, precise computational accounts of these effects are limited. Mental representation refers to the ability to encode, manipulate, and process information efficiently to achieve goals. How information is represented in turn constrains our ability to make effective decisions and recollect past experience. We created a novel behavioral task that enables the independent measurement of visual working memory and decision making. We induced physiological and psychological stress in half of our participants to measure the impact of stress on the formation of mental representations. We then developed a novel computational cognitive model based on a beta-variational autoencoder that can optimize its learned representations subject to information-theoretic constraints. This model enables us to quantify how mental representations for complex visual information are constrained by limited cognitive resources. The parameters of the model include a tradeoff between the complexity of representations and fidelity of reconstructions, along with parameters that control how the model prioritizes the encoding and representation of features relevant for performing the task. Our model captures the patterns of memory errors made by human participants which enables us to quantify individual differences regarding the impact of stress on high-level cognition.

Sub-clinical psychiatric symptom dimensions are associated with shifts in metacognitive bias but not metacognitive noise.

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Session:
Symposium: Computational Models Of Confidence And Metacognition

Metacognition refers to the ability to understand and reflect on one's own cognitive processes. Model-based analysis approaches have been developed to allow for quantification and separation of latent metacognitive processes. This is important because metacognition is influenced by multiple potentially orthogonal characteristics including metacognitive sensitivity (the degree to which confidence dissociates between correct and incorrect decisions), metacognitive bias (the absolute level of confidence reported regardless of objective accuracy), and by 1st-order task performance itself.
Many studies have shown that both clinical and sub-clinical symptoms of psychopathology are associated with systematic metacognitive alterations. For instance, anxiety and depression are associated with metacognitive bias towards low confidence. However, results concerning metacognitive sensitivity have been mixed, potentially due to difficulties in its measurement such as confounding by first-order task performance. A recently developed process model of metacognition (ReMeta) may provide a more optimal means of estimating both sensitivity and bias independently of first-order task performance. Here, we investigated relationships between psychiatric symptom dimensions and perceptual metacognition in a large general population sample (N>1000) using measures derived from ReMeta. The results confirmed robust relationships between symptom dimensions and metacognitive bias: An anxious-depression symptom dimension was characterised by systematic underconfidence in perceptual decisions, whereas a compulsivity symptom dimension was was characterised by systematic overconfidence. In contrast, little to no evidence was found for any symptom-related alterations in metacognitive noise/sensitivity. Sub-clinical psychiatric symptom dimensions are not associated with a reduction in metacognitive insight but rather with changes in the absolute levels of confidence reported.

ReMeta toolbox: inferring latent metacognitive parameters from confidence datasets

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Session:
Symposium: Computational Models Of Confidence And Metacognition

The ability to introspect and communicate confidence about one's thoughts, actions, and perceptions is a defining feature of human behavior. In addition, there is evidence for substantial interindividual variation of metacognitive abilities from clinical, educational and personality research. To better understand these interindividual differences and underlying mechanisms, there is increasing interest in inferring latent metacognitive parameters from empirical datasets involving confidence ratings. These parameters broadly fall in two categories: metacognitive biases and metacognitive inefficiencies.
In this talk, I will present the ReMeta toolbox as a flexible framework to enable such inferences. Researchers can specify a generative model (e.g., expected metacognitive noise distribution) and metacognitive bias and noise parameters at different levels of the processing hierarchy. In particular, researchers can indicate whether metacognitive noise is more likely to occur at the readout stage (e.g., a metacognitive module reading out sensory evidence) or at the report level. I will demonstrate parameter and model recovery results for the default models of the toolbox and provide validation with empirical data. Current opportunities and remaining challenges are discussed.

Learning how to compute confidence

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Session:
Symposium: Computational Models Of Confidence And Metacognition

When making a decision, individuals tend to be more accurate when they report higher confidence in their decision. This observation led to the proposal that confidence reflects the posterior probability of making a correct response, given relevant data. In the drift diffusion model framework, this probability is determined by both the total amount of evidence sampled and accumulation time. To adequately compute confidence, one thus needs to learn the proper mapping from their readout of their decision process (i.e. evidence and time) to the corresponding probability of the decision being correct (further referred to as confidence mapping). The exact mechanical underpinnings of this learning process are still mostly unknown, as current computational models of confidence often implicitly assume this learning to be terminated. In this work, we present a new modelling framework where the confidence mapping is instead continuously updated according to feedback. We tested this model as well as the proposal that humans learn the confidence mapping from feedback in two perceptual decision making experiments where participants were alternating between two different feedback contexts. As predicted, confidence ratings progressively increased (resp. decreased) after switching into high (resp. low) feedback blocks, while objective performance (i.e. accuracy and reaction time) was not affected by feedback. Importantly, our learning model was able to precisely capture this evolution of confidence over time. Overall, this work highlights the importance of taking into account the dynamics of the computation of confidence, and sheds new lights on how confidence biases and other metacognitive inefficiencies may emerge.

The importance of accumulation time in the computation of confidence

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Session:
Symposium: Computational Models Of Confidence And Metacognition

The computation of confidence judgments in decision-making crucially depends on decision time. This study delves into the role of accumulation time in sequential sampling models of confidence, exploring optimal confidence computation in a Bayesian observer model and fitting empirical data to dynamical confidence models. The formal analysis of the posterior probability of being correct highlights that an optimal observer discounts final available evidence by the accumulation time. Additionally, optimal confidence incorporates evidence about task difficulty when such evidence is available independent of the evidence about stimulus category.
We introduce the dynamical visibility, time, and evidence model (dynaViTE), which assumes post-decisional evidence accumulation and accumulation of independent information about stimulus visibility and specifically incorporates accumulation time in confidence determination. We fitted the dynaViTE model to data across four experiments, including three experiments with difficulty manipulations and one experiment with both manipulation of discriminability and a speed-accuracy trade-off manipulation. DynaViTE shows a good fit to observed data, accounting for all observed data patterns. Quantitative model comparisons suggest that human observers leverage accumulation time as a pivotal factor in confidence computation. Significantly, accumulation time affected confidence, even when the observed correlation between response times and confidence was small.
The weight participants assigned to the three components - evidence, visibility, and accumulation time - varied considerably across the examined experiments. This variability suggests that individuals can adapt their calculations to the specific situation. Currently, the conditions modulating these weights remain unclear. We present potential mechanisms based on Bayesian confidence and the dynaViTE model.

Select-a-frame: constructing comprehensive and comparable metacognitive behavioral profiles

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Session:
Symposium: Computational Models Of Confidence And Metacognition

Metacognitive bias, particularly positive evidence bias, is a useful tool for studying metacognition since it allows a clear dissociation between confidence behaviors and the accuracy of primary perceptual processes. Our motivating question for this study asks to what extent these kinds of metacognitive biases are similar or generalizable across different types of tasks. We have created a novel online library of four 3-Alternative Forced Choice perceptual (PTs) and cognitive/value-based (C/VTs) reaction time behavioral tasks to collect within-subject measures of performance ("T1") and confidence ("T2") within 14 distinct conditions that are shared across all tasks. We use this library to characterize metacognitive behavioral profiles (BPs) for each subject in each task, i.e. quantitative "fingerprint"-like relationships between performance and confidence. To quantify each BP we built a choice frequency distribution for each presented choice defining T1-BP for each condition within each task. For T2-BP for each condition within each task, we calculated the average confidence rating conditioned on choice. We computed T1-BPs and T2-BPs in this way for all tasks and for all conditions. Then, we quantified the similarity in BPs (defined by the combination of T1-BPs and T2-BPs) within every condition but across tasks using sum of squared error (SSE) as a dissimilarity metric. To test for systematic differences, we calculated mean SSE1 and SSE2 for all pairs of tasks, across all conditions. We found less dissimilarity within PTs T1-BPs and C/VTs T2-BPs and more dissimilarity within PTs T2-BPs and C/VTs T1-BPs.

Computational Modelling of Post-decisional EEG Markers Informing Confidence

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Session:
Symposium: Computational Models Of Confidence And Metacognition

Decision confidence refers to a person's subjective judgement of the accuracy of their decision. It is thought to be a key (meta)-cognitive function to evaluate performance and adjust future behaviour. It has been suggested that decision confidence arises as the result of a post-decisional evidence accumulation process. Recently, the error positivity (Pe) signal recorded using response-locked EEG was proposed as a neural correlate of this post-decision evidence accumulation process (Desender et al., 2021), given that it has already been associated with error detection, confidence rating, and future behaviour adjustments. However, direct evidence for a link between single-trial Pe and post-decision evidence accumulation is currently lacking. In this EEG study, we jointly fit the Pe signal and choice-response times (choice-RTs) with an extended drift-diffusion model. This model has additional boundaries for confidence that allow us to model the post-decisional accumulation process. We hypothesized that the amplitude of the Pe signal would predict the confidence rating of the subject, such that the higher the amplitude of the Pe signal, the lower the confidence. We also expected that the higher the amplitude of the Pe signal, the slower the post-decision evidence accumulation process would be. We used two approaches for modeling: the chi-square method, and a Bayesian likelihood-free parameter estimation method (Bayesflow; Radev et al., 2022) which leverages invertible neural networks. We found weak positive relationships between Pe signal amplitude and post-decision evidence accumulation. We talk about these results in context of the literature on decision confidence.

From perception to confidence: Leveraging natural image statistics

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Session:
Symposium: Computational Models Of Confidence And Metacognition

In an environment rife with perceptual ambiguity and minimal external feedback, decision confidence plays a vital role in the adaptive control of behaviour. Despite the functional significance of decision confidence, the computational processes underlying confidence judgements in perceptual decisions have yet to be clearly characterised and remain the topic of ongoing debate. To better understand these mechanisms, in this study we sought to address the extent to which prior knowledge informs confidence. Contrary to previous research, we did not require participants to internalise an arbitrary, context-specific prior distribution. Instead, we used a novel psychophysical paradigm which allowed us to capitalise on probability distributions of low-level image features in natural scenes, which are well-known to influence perception. Participants reported the subjective upright of naturalistic image target patches, and then reported their confidence in their orientation responses. We used modelling to relate the probability distributions of low-level image features in natural scenes to the probability distributions of the same low-level features in the targets. As expected, we found that participants' orientation judgements were consistent with an internalised prior of natural scene statistics. Critically, these same distributions also predicted participants' confidence judgements. Our findings highlight the importance of using naturalistic task designs that capitalise on existing, long-term priors to further our understanding of the computational basis of confidence.

Linear ballistic accumulator models of confidence and response time

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Session:
Symposium: Computational Models Of Confidence And Metacognition

Accurate decisions tend to be both confident and fast. Nonetheless, there are relatively few models that can simultaneously address this three-way relationship, especially for single stage decisions where participants indicate both their choice and their confidence. Extending on a common decision architecture of the linear ballistic accumulator framework, three models have been proposed – 1) a Multiple Threshold Race model which instantiates the Balance-of-Evidence hypothesis where confidence is determined through the difference between accumulated evidence for competing options (e.g., Reynolds, Osth, Kvam, & Heathcote, in revision), 2) a newly developed Confidence Accumulator model which assumes that confidence itself is accumulated independently for each confidence option, and 3) a newly developed Timing model which assumes confidence can be derived from subjective time. To test these three confidence architectures, we ran two experiments manipulating the length of the confidence rating scale across 2-, 4-, or 6-options in a recognition memory task along with a perceptual task. Different models were compared that made different allowance for how the length of the confidence scale affected model parameters. While both model classes found that thresholds were affected by the length of the scale, drift rates were only minimally affected. Implications for models of confidence and response time will be discussed.

Memory activation and retrieval strategy in lexical alignment: Comparing the ACT–R model of human and computer interlocutors

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Session:
ICCM: Linguistic Phenomena

During conversations, speakers tend to reuse the lexical expressions of their interlocutors. This is called “lexical alignment,” and it facilitates the listener’s understanding of the speaker’s intention. Branigan (2011) has shown that this tendency increases when speakers believe that their partner is a computer agent rather than a human. Memory activation for the expressions used by the interlocutors and the strategy preference whereby speakers attempt to use their partners’ expressions rather than those that first come to mind have been shown to be the causes of lexical alignment. For this study, we constructed an ACT–R model for which we could adjust the parameter values related to these two features. Through parameter adjustment, we simulated lexical alignment with both human and computer agents. For both partner conditions, additional activation was added to the knowledge of the partners’ expressions. The computer–partner model preferred trying to retrieve the partners’ expression rather than using the knowledge that had a strong association with the stimulus and was easy to retrieve. In contrast, the human–partner model had no specific preference; that is, it displayed equal utility for both. A comparison of these parameter values revealed that the computer–partner model preferred to retrieve the partner’s knowledge; in addition, it also kept the knowledge’s activation sufficiently high so that it could be available for a longer duration.

Exploring an Approach for Phonological Awareness Estimation Employing Personalized Cognitive Models and Audio Filters

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Shizuoka University

Morita, Junya
Shizuoka University

Session:
ICCM: Linguistic Phenomena

Language development is supported by phonological awareness, which is related to attention to phonological aspects of spoken language. We aim to develop a system that supports phonological awareness formation using cognitive models. Estimating the state of a user’s phonological awareness is a kind of identification of the user’s "auditory filter." This paper reports on an experiment with typically developed native speakers by setting up an audio filter that is applied to the system’s output sound. The user’s phonological awareness is estimated as a relative preference for two computational models presented by the system. Using the system with audio filters, we test the hypothesis that there is a difference in participants' selection behavior depending on the characteristics of the model under the application of the audio filter. The results of the experiment showed that there was a difference in the selection probability between models only when a specific audio filter was applied.

Intractability obstacles to explanations of communication

Even when talking about novel things and without a fully shared vocabulary, people can come to understand each other through communicative turn taking (what we call communicative alignment). State-of-the-art computational models cannot yet explain this capacity, because (1) empirically corroborated models only work under shared knowledge and vocabularies, and leave out interactive processes needed to overcome misalignment; (2) models that do include misalignment and interactive processes cannot account for communicative successes under real-world conditions; and (3) models that overcome the limits in (2) use a theoretical 'hack'. In this paper, we add a challenge to the list: the interactive processes in both models of type (2) and (3) are intractable. We explore the robustness and implications of this theoretical challenge for models of communicative alignment in general.

van de Braak, Laura
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de Haan, Ronald

Dingemanse, Mark

Toni, Ivan

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Blokpoel, Mark
Radboud University, Nijmegen

Session:
ICCM: Linguistic Phenomena

Challenges for a Computational Explanation of Flexible Linguistic Inference

We identify theoretical challenges for developing a computational explanation of flexible linguistic inference. Specifically, the human ability to interpret a novel linguistic expression (like mask-shaming), where inferring plausible meanings requires integrating relevant background knowledge (e.g., COVID-19 pandemic). We lay out (i) the core properties of the phenomenon that together make up our construal of the explanandum, (ii) explanatory desiderata to help make sure a theory explains the explanandum, and (iii) cognitive constraints to ensure a theory can be plausibly realised by human cognition and the brain. By doing so, we lay bare the 'force field' that theories of this explanandum will have to navigate, and we give examples of tensions that arise between different components of this force field. This is an important step in theory-development because it allows researchers who aim to solve one part of the puzzle of flexible linguistic inference to keep in clear view the other parts.

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Session:
ICCM: Linguistic Phenomena

A Proposal for Extending the Common Model of Cognition to Emotion

Cognition and emotion must be partnered in any complete model of a humanlike mind. This article proposes an extension to the Common Model of Cognition – a developing consensus concerning what is required in such a mind – for emotion that includes a linked pair of modules for emotion and metacognitive assessment, plus pervasive connections between these two new modules and the Common Model's existing modules and links.

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Granger, Richard
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Session:
ICCM: Emotion & Cognition

How to Provide a Dynamic Cognitive Person Model of a Human Collaboration Partner to a Pepper Robot

For a successful and trustful human-robot interaction the challenge is to provide the robot with information to dynamically adapt appropriately to a person and changing situations. Cognitive architectures such as ACT-R provide valuable capabilities to address this challenge. This paper gives an example on how exactly cognitive architectures can be used to provide better human-robot interaction. First, this paper shows how mental representations can be build up to anticipate
the partner and the situation in order to collaborate adaptively. Second, it is shown how to integrate a model with a robot in a simple way. And third, an example is shown how emotion recognition can be used as an example of adapting the interaction accordingly by using perceived changes in the real world. As results the paper gives instructions, concepts and usecase examples on the realization of the different aspects. The paper encourages further research on how cognitive architectures can address challenges in human-aware AI.

Werk, Alexander
Technische Universität Berlin

Scholz, Sina
Universität zu Lübeck

Sievers, Thomas
Universität zu Lübeck

Russwinkel, Nele

Session:
ICCM: Emotion & Cognition

The Computational Mechanisms of Detached Mindfulness

We present a computational approach to the mechanisms involved in a type of metacognitive monitoring known as detached mindfulness, a particularly effective therapeutic technique within cognitive psychology. We employ a computational model of metacognitive skill training, founded on the Common Model of Cognition, to articulate the mechanisms through which a detached perception of affect reduces emotional reactivity.

Conway-Smith, Brendan
Carleton University

West, Robert
Carleton University

Session:
ICCM: Emotion & Cognition

Trait Inference on Cognitive Model of Curiosity: Relationship between Perceived Intelligence and Levels of Processing

Cognitive models are used as simulators that derive external behavior from assumed internal states. As a tool for linking external behavior with internal causes, cognitive models can be used to examine human trait inference on others. While fundamental attribution errors are identified in social psychology, the specific factors remain unclear. By employing detailed cognitive models to specify internal states, it is possible to deepen our understanding of human inference on internal processes. In this study, we utilized the ACT-R cognitive architecture to construct such internal states and externalized behaviors. We also focused on 'curiosity' as an individual trait emphasized in real society to evaluate individuals. We developed a visualizer for the behavior of multiple models of curiosity and conducted subjective evaluations with participants recruited from a Japanese crowdsourcing site. As a result, we observed differences in inferred traits among models, although the specific patterns were not consistently aligned with the model assumptions. Additional analysis revealed that participants' inferences were more influenced by observable behavior patterns rather than internal processes, indicating a deficit in human attribution as suggested by the tradition of social psychology.

Nagashima, Kazuma
Shizuoka University

Morita, Junya
Shizuoka University

Session:
ICCM: Emotion & Cognition

Predicting complex problem solving performance in the tailorshop scenario

Brand, Daniel
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Todorovikj, Sara
Chemnitz University of Technology

Ragni, Marco
TU Chemnitz

Session:
ICCM: Problem Solving Skills

Complex problem solving (CPS) is a fundamental capability of humans. It is often studied through microworlds, with the Tailorshop-scenario as a well-investigated prominent example. This paper addresses several research questions for CPS in the Tailorshop scenario: Firstly, it examines the impact of background knowledge vs. understanding underlying dynamics. Secondly, it investigates the predictability of a participants' performance, particularly when considering their assumptions about the scenario's mechanisms. Finally, it discusses the suitability of the Tailorshop as a scenario for cognitive modeling of CPS. Thereby, we discuss some of the measures that have been proposed to assess CPS performance, considering CPS from an perspective of predictive modeling.Based on our results, we conclude that effective prediction of outcomes in complex tasks necessitates uniform impact of actions throughout, facilitating comprehension of both overarching strategies and smaller adjustments crucial in real-world problem-solving domains.

"I Knew it!" Model-Based Dissociation of Prior Knowledge Confounds in Memory Assessments

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Stocco, Andrea
University of Washington

Williams, Alyssa
Mississippi State University

Session:
ICCM: Problem Solving Skills

Computational modeling is a powerful approach for discerning individual differences in memory function. The model-based assessments discussed in this paper rely on estimating an individual's rate of memory decay– a stable and idiographic parameter that the model can capture. However, this paper aims to demonstrate prior knowledge as a confounding factor in these model-based assessments and seeks to parse out the error using Maximum Likelihood Estimations. The metric of individualized memory performance, termed Speed of Forgetting, was significantly lower for facts known beforehand. Still, these facts were identified with 81% accuracy by recovered base-level activation estimations blind to the ground-truth data. A proposal for future model-based assessments to account for prior knowledge is discussed.

Model verification and preferred mental models in syllogistic reasoning

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Chemnitz University of Technology

Brand, Daniel
Chemnitz University of Technology

Ragni, Marco
TU Chemnitz

Session:
ICCM: Reasoning Patterns

A core cognitive ability of humans is the creation of and reasoning with mental models based on given information. When confronted with indeterminate information, allowing for the existence of multiple mental models, humans seem to recurrently report specific models - so-called preferred mental models.
In this paper, we revisit this within the context of syllogistic reasoning, which involves statements about quantified assertions. We present an experiment designed to investigate the verification process of preferred mental models. Our analysis centers on two primary research questions: Is model verification generally straightforward for reasoners? And does a preference effect for specific models exist in syllogistic reasoning? Furthermore, employing modeling techniques, we delve into analyzing structural complexity of mental model, based on the types of instances they consist of. We discuss our findings and their implications on the differences between reasoning with syllogisms and spatial statements.

Predictive Algorithms for Individual Reasoning about Possibilities

Ragni, Marco
TU Chemnitz

Johnson-Laird, Phil

Session:
ICCM: Reasoning Patterns

How do people reason about possibilities in everyday life? Most cognitive scientists, including readers of this article, are likely to believe that they rely on a logic, albeit one beyond the grasp of introspection. Logics exist for dealing with possibilities—modal logics, and they are useful in software engineering and other domains. This article describes the mental model theory of possibilities, and reports two experiments corroborating its central claim that individuals make inferences in default of knowledge to the contrary—a principle inconsistent with all standard modal logics. It also shows that the theory's implementation in a computer program, mModal, accounts for differences from one individual to another in how they reason about possibilities.

Rational Compression In Choice Prediction

Taylor-Davies, Max
University of Edinburgh

Lucas, Christopher

Session:
ICCM: Reasoning Patterns

To successfully navigate its social environment, an agent must construct and maintain representations of the other agents that it encounters. Such representations are useful for many tasks, but they are not without cost. As a result, agents must make decisions regarding how much information they choose to store about the other agents in their environment. Using choice prediction as an example task, we illustrate the problem of finding agent representations that optimally trade off between downstream utility and information cost, before presenting the results of two behavioural experiments designed to examine this tradeoff in human social cognition. We find that people are sensitive to the balance between representation cost and downstream value, while still deviating from optimality.

Dissecting the Drivers of Change Points in Individual Learning: An Analysis with Real-World Data

Collins, Michael
Cognitive Models and Agents Branch

Sense, Florian
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Krusmark, Michael

Myers, Tiffany (Jastrzembski)
Air Force Research Laboratory

Session:
ICCM: Learning Processes

Many different theories of learning have been developed to account for human performance over time, often accounting for performance at an aggregate level. Understanding performance at an individual level is often more difficult because of multiple different factors—e.g., noise, strategy selection, or change in memory representation—, which are often not ac- counted for in simple learning theories. One approach used to explain the sudden changes in performance that are often observed at the individual level is to integrate change detection algorithms with psychological models. This research has shown that performance at the individual level can be understood not by a single continuous process but instead by segmented portions of multiple processes. Previous research has posited different explanations as to what features drive the inferences of change points. However, no paper has yet compared different explanations' ability to explain the variance in inferred change points. In this paper, we use a simple model of learning to account for performance in a real-world data set with individuals performing multiple different games that tap into different task attributes (i.e., memory, attention, problem-solving) on the website Luminosity. We then conduct a statistical analysis to determine what drives change points in the dataset. The results here allow for better clarification as to what features are driving the inferences of change points at the individual level.

Genetically evolving verbal learner: a computational model based on chunking and evolution

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London School of Economics and Political Science

Javed, Noman

Lane, Peter
University of Hertfordshire

Gobet, Fernand

Bartlett, Laura

Session:
ICCM: Learning Processes

A fundamental issue in cognitive science concerns the interaction of the cognitive "how" operations, the genetic/memetic "why" processes, and by what means this interaction results in constrained variability and individual differences. This study proposes a single GEVL model that combines complex cognitive mechanisms with a genetic programming approach. The model evolves populations of cognitive agents, with each agent learning by chunking and incorporating LTM and STM stores, as well as attention. The model simulates two different verbal learning tasks: one that investigates the effect of stimulus-response (S-R) similarity on the learning rate; and the other, that examines how the learning time is affected by the change in stimuli presentation times. GEVL's results are compared to both human data and EPAM – a different verbal learning model that utilises hand-crafted task-specific strategies. The automatically evolved GEVL strategies produced good fit to the human data in both studies, improving on EPAM's scores by as much as factor of two on some of the pattern similarity conditions. These findings offer further support to the mechanisms proposed by chunking theory, connect them to the evolutionary approach, and make further inroads towards a Unified Theory of Cognition (Newell, 1990).

Modeling Instance-Based Rule Learning in an Adaptive Retrieval Practice Task

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University of Groningen

Braam, Myrthe

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InfiniteTactics, LLC

van Rijn, Hedderik
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Session:
ICCM: Learning Processes

Model-based adaptive learning systems have successfully improved the efficiency of fact learning in educational practice. Typically, such systems work by keeping track of a learner's memory processes by measuring behavior during learning, and using this information to tailor the learning process towards the needs of individual learners. Where many adaptive learning systems applied today focus on learning paired associates, we here focus on learning grammar rules based on instances of these general rules. We show that participants' (N = 42) behavioral responses on instance questions for a rule can be used to infer general performance on other ques- tions associated to that rule, and that we can capture this rule perfor- mance in a single model-based speed of forgetting parameter. These findings could be used to develop and optimize adaptive learning systems that can be used to study general rules from instances.

How to Match Cognitive Model Predictions with EEG data

Preuss, Kai
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Session:
ICCM: Neuroscience Models

Reliably identifying relevant brain areas implicated by the simulated activity from cognitive models is still an unsolved problem for cognitive modeling, particularly when matching model output with human electroencephalography (EEG) data. We propose a new method involving post-processing of ACT-R module activity and clustered EEG component activity with generalized least squares (GLS) analysis to find matching patterns between predicted and observed data, thereby inferring neural substrates of distinct cognitive processes. This approach holds several advantages over other methods by controlling for autocorrelation and unequal variances. To exemplify its application, we used a cognitive model and EEG data from a mental spatial transformation study to show how this method finds areas involved in representational and transformational spatial processing. Parietal areas involved with spatial activity were identified, in line with prior studies on spatial cognition. In addition, previously established associations between ACT-R and brain areas were confirmed. Finally, we discuss limitations and possibilities of the approach.

A Neuro-Symbolic Implementation of Mouse Reward Timing Learning

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Centre for Theoretical Neuroscience, University of Waterloo, Canada

Session:
ICCM: Neuroscience Models

Animals and humans in reinforcement learning tasks are able to learn the timing of reward delivery, even when that timing is delayed and variable, suggesting a sophisticated ability to learn the distribution of reward timings. In this work, we present two algorithms simulating the switching interval variance (SIV) task as described in Li et al. that showed mice were able to adapt their behaviour to the change of standard deviation of the reward time delays. Both algorithms implementthe wait vs stay decision by thresholding the log evidence that a forthcoming reward is likely, without assuming the specific form of the reward timing distribution. One algorithm is implemented algebraically, and the other using Spatial Semantic Pointers, a tool from Vector Symbolic Algebras for representing continuous values that have ties to hippocampal grid cells. We show that our models capture characteristic behaviour of mice on the SIV task.

Simulating event-related potentials in bilingual sentence comprehension: syntactic violations and syntactic transfer

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Session:
ICCM: Neuroscience Models

Event-related potentials (ERPs) are used to study how language is processed in the brain, including differences between native (L1) and second-language (L2) processing. A P600 ERP effect can be measured in proficient L2 learners in response to an L2 syntactic violation, indicating native-like processing. Cross-language similarity seems to be a factor that modulates P600 effect size. This manifests in a reduced P600 effect in response to a syntactic violation in the L2 when the syntactic feature involved is expressed differently in two languages. We investigate if this reduced P600 effect can be explained by assuming that ERPs reflect learning signals that arise from mismatches in predictive processing; and in particular that the P600 reflects the error that is back-propagated through the language system (Fitz & Chang, 2019). We use a recurrent neural network model of bilingual sentence processing to simulate the P600 (as back-propagated prediction error) and have it process three types of syntactic constructions differing in cross-language similarity.
Simulated English-Spanish participants displayed a P600 when encountering constructions that are similar between the two languages, but a reduced P600 for constructions that differ between languages. This difference between the two P600 responses mirrors what has been observed in human ERP studies. Unlike human participants, simulated participants showed a small P600 response to constructions unique to the L2 (i.e., grammatical gender), presumably because of how this grammatical feature is encoded in the model. Our modelling results shed further light on the viability of error propagation as an account of ERPs, and on the effects of syntactic transfer from L1 to L2.

Computational mechanisms underlying latent value updating of unchosen actions

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Session:
ICCM: Problem Solving Skills

Current studies suggest that individuals estimate the value of their choices based on observed feedback. Here, we ask whether individuals also update the value of their unchosen actions, even when the associated feedback remains unknown. One hundred seventy-eight individuals completed a multi-armed bandit task, making choices to gain rewards. We found robust evidence suggesting latent value updating of unchosen actions based on the chosen action's outcome. Computational modeling results suggested that this effect is mainly explained by a value updating mechanism whereby individuals integrate the outcome history for choosing an option with that of rejecting the alternative. Properties of the deliberation (i.e., duration/difficulty) did not moderate the latent value updating of unchosen actions, suggesting that memory traces generated during deliberation might take a smaller role in this specific phenomenon than previously thought. We discuss the mechanisms facilitating credit assignment to unchosen actions and their implications for human decision-making.

Exploring Analogical Transfer with Tower of Hanoi Isomorphs

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Session:
ICCM: Problem Solving Skills

Analogical reasoning is a core cognitive process that involves mapping knowledge structures, and may depend on how mental representations are encoded and retrieved. Successful analogical reasoning can enable analogical transfer between a previous and new concept or problem. Theories and models were developed to explain analogical reasoning and transfer. However, challenges with interacting cognitive processes, generalization, and cognitive plausibility remain. Here, we attempt to address challenges by leveraging previous work with a cognitive analogical reasoning framework and a subsequent extension. The model starts with procedural knowledge about how do a problem solving task and learns its solution. It then "reads" and represents problem isomorphs, and initiates analogical transfer to solve them. We present results and limitations with our approach.

Exploring the steps of learning: computational modeling of initiatory-actions among individuals with attention-deficit/hyperactivity disorder

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Session:
ICCM: Learning Processes

Attention-deficit/hyperactivity disorder (ADHD) is characterized by difficulty in acting in a goal-directed manner. While most environments require a sequence of actions for goal attainment, ADHD was never studied in the context of value-based sequence learning. Here, we made use of current advancements in hierarchical reinforcement-learning algorithms to track the internal value and choice policy of individuals with ADHD performing a three-stage sequence learning task. Specifically, 54 participants (28 ADHD, 26 controls) completed a value-based reinforcement-learning task that allowed us to estimate internal action values for each trial and stage using computational modeling. We found attenuated sensitivity to action values in ADHD compared to controls, both in choice and reaction-time variability estimates. Remarkably, this was found only for first-stage actions (i.e., initiatory actions), while for actions performed just before outcome delivery the two groups were strikingly indistinguishable. These results suggest a difficulty in following value estimation for initiatory actions in ADHD.

The value of environmental and health outcomes under delay and risk

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Session:
Social Cognition

Investments in public health or environmental sustainability require funding agencies to choose which proposals have the most valuable outcomes, but little is known about how the subjective value of environmental and health outcomes change in the face of delay and risk. This talk investigates the cognitive mechanisms that influence the subjective value of sea-level rise (environmental), diagnoses of tobacco-use related illness (health), and monetary losses when choosing between outcomes and when pricing outcomes in isolation. Experiment 1 explored how these outcomes are valued under delay and risk independently. Experiment 2 tested the value of these outcomes when they are both delayed and risky. Cognitive models of the choice and pricing tasks were used to compare changes in subjective value between the outcomes and tasks through parameters that represent the underlying cognitive processes involved in determining the value of a delayed and/or risky outcome. Results suggest that pricing favors larger outcomes compared to choice and that this effect is primarily driven by anchoring on the outcome and a higher sensitivity to the outcome during pricing. Monetary and environmental outcomes generally showed more similarities to one another than to health outcomes, with the most serious health outcomes retaining relatively more value in the face of long delays or low probabilities of receipt than monetary or environmental outcomes.

Testing different accounts of the contiguity effect: A causal and symmetrical one

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Session:
MathPsych Posters

In free recall, consecutive recalled words tend to be positioned nearby in the study list, depicted as the contiguity effect, with an asymmetry favoring forward recalls. This robust effect, which has been observed in many experimental settings and with multiple manipulations, can be explained by causal and noncausal models of episodic memory. Causal models such as SAM or TCM suggest that each recalled word is used as a probe for the next recall; whereas noncausal models such as the model of Davelaar et al. (2005), suggest a correlation between the mental states of study and test phases, to explain the contiguity effect. In an attempt to disrupt the suggested correlation between mental states, Kılıç et al. (2013) devised the probed recall task, which involves making a recall from the same list using the provided probe, after studying several lists. Their results suggested that the contiguity effect remains intact, although symmetric, even when the correlation is disrupted and supported causal accounts. This study aimed to increase performance in the probe recall task to understand whether the symmetry was caused by the lower performance obtained in the experiment by using event segmentation. Different distractor tasks between each list were presented to participants to increase discrimination of lists from each other. The results indicated a symmetric but intact contiguity effect even when performance is increased, depicted in a conditional response probability (CRP) curve, supporting causal explanations of the effect.

Explaining two kinds of repulsion biases in perception and decision making

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Session:
MathPsych Posters

There are multiple repulsion biases in perceptual decision making. In motion transparency, the perceptual experience of two superimposed coherent motions is biased toward repulsion when the angle between the two exceeds 30 degrees (Braddick et al., 2002). Moreover, in decision making, when a discrimination task proceeds a perceptual judgement task, the former biases the latter away from the discrimination reference probe (the repulsion effect; Zamboni et al., 2016; Spicer et al., 2022). Can these two repulsive effects co-occur and what kind of model could explain such co-occurrence?

We presented participants with transparent motion stimuli and asked participants to perform two tasks sequentially: a motion direction discrimination task relative to a reference probe and then a motion direction report task of all observed motion groups. The perceptual repulsion effect and the decision-making repulsion effect were replicated independently. The reported direction relative to the probe stimulus was biased away from the probe from the discrimination task, but only when participants performed a discrimination task first. A separate experiment confirmed that the bias away from the probe was a decision-making bias that was attenuated by a pause after the discrimination task.

How can we provide a unified explanation of both repulsion biases? Bayesian models can explain the repulsion between two transparent motions as the result of inference using an internal generative model (Gershman et al., 2016), specifically inferring and subtracting the joint motion of the stimuli, while evidence accumulation models explain the repulsion effect in decision making (Spicer et al., 2022). We propose that the brain sequentially samples from the posterior distribution over the generative model given the stimuli (capturing repulsion between the motions) with optimal stopping (capturing repulsion from the probe).

Dimensional Effects of Stimuli of Visual Cues on Military Pilots

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Session:
MathPsych Posters

Current research for military pilots tends to frequently center on the amount of information made available for the individual based on perceptual modeling - emphasizing cognitive information processing for anticipated incidents or simple outcomes. However, although these analyses account for a process explanation description in decision-making, it does not posit the perceptual effects of decision-making on task performance based on multiple visual cues and stimuli under extreme visual conditions – as the varied dimensions of a stimulus do not necessitate straightforward effects when adjusting each cue alone. By changing and adapting the multiple facets of stimuli, we can detect which cues aid in identifying the needed visual information to increase and maintain the fastest and most precise decision responses through visual perception processing. We suggest that through the General Theory Recognition Model (GRT), we can examine multidimensional stimuli to develop and regulate the best properties to support aviation cues and symbology. This study is designed to investigate visual information stimuli and disruption through filtered overlays/varying backgrounds/various cues that may directly or indirectly affect the task or information processing of the participant. Manipulated symbols, such as those with applied color-specific filters or non-neutral backgrounds, showed increased speed performance in symbol recognition within the visual range, including visual stimuli in a more peripheral zone. Applied filters may aid in faster detection of visual cues but may change the overall meaning of the specified symbol, creating a need to verify the intended connotation without loss of speed or accuracy in task performance and identification.

Bayesian methods for dataset-integrated model evaluation of cognitive models: A case of forgetting curves

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Okada, Kensuke
The University of Tokyo

Session:
MathPsych Posters

With the growing movement toward robust modeling in response to the crisis of reproducibility in psychological research, it is a crucial practice to test whether an existing model can explain other datasets and evaluate the differences in model behavior that can be observed between different datasets. The framework of secondary data analysis, in which studies are conducted using existing data, is helpful for such efforts because it allows for the use of a wide variety of datasets containing minor differences in experimental conditions and other details, thus contributing to validating the robustness of the model. In this study, using models representing the form of a mathematical function of the forgetting curve as an example, we considered how to evaluate models in a dataset-integrated manner using multiple secondary datasets. Specifically, we implemented Bayesian hierarchical models that account for the differences among datasets based on a meta-analytic approach. Then, using the Bayesian Evidence Synthesis framework, we repeatedly fitted the models with sequential additions of datasets and observed the transition of the Bayes Factors. We report the results of the preliminary simulation study. We constructed power and linear models that explain the forgetting curves using power and linear functions, respectively, and compared these two models with artificial datasets. The results confirmed that the Bayes Factors correctly chose data-generating models in situations where the data-generating models were known. Moreover, we discuss our preregistered protocol for secondary data analysis that we plan to conduct.

Bayesian methods for inference with large datasets

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Session:
MathPsych Posters

Bayesian inference requires the use of numerical solutions since posterior distributions in closed-form are rarely computable in complex models. Popular algorithms and specialized software demand a considerable amount of computational resources and Bayesian analyses requiring hours or days of uninterrupted computation are common. Furthermore, the need for scalable Bayesian methods intensifies as large datasets on diverse domains become readily available.

In this work we explore the performance of Consensus Monte Carlo (CMC) in the context of hierarchical models. This distributed algorithm splits the data into several different chunks and assigns each one to a different machine, calculates the posterior distribution corresponding to each data partition, and then mixes them back together to obtain the posterior distribution reflecting the whole dataset, where the final "consensus" distribution is a weighted average of the posterior distributions returned by each machine.

We illustrate the workings of CMC by implementing a hierarchical model of choice equilibrium over NFL play-by-play decisions. The dataset includes over a quarter million plays from 2013 to 2023 and, given its moderate size, allows for a direct comparison between CMC and the model implemented in a single machine using all observations at once. The hierarchical model we use as example describes choices between rushing or passing as a function of the relative gain in yards returned by each of those alternatives, and explains deviations from optimal equilibrium in terms of covariates at team, game, and quarter level.

Comparing hypothesis tests using regions of support

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Meyen, Sascha
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University of Tübingen

Session:
MathPsych Posters

Hypothesis testing is one of the most widely used tools in inferential statistics. Yet, hypothesis tests — be it frequentist or Bayesian — have their respective problems and can cause sever misinterpretations. We argue that one reason for these persistent problems is the following discrepancy: While hypothesis tests are explicit on which parameter-values are theoretically contained in each hypothesis, they are usually not explicit on which parameter-values would in a practical setting lead (most likely) to which test outcome. For example, certain small 'true' effects although deviating from the typical point-null hypothesis will in most cases lead to Bayes Factors supporting the null hypothesis depending on the sample size (or, more generally, precision). To make these test-characteristics explicit we introduce the concept of Regions of Support (ROS). ROS can serve both as a check for researchers' expectations as well as a comparison of different tests. We evaluate standard Bayesian and frequentist point-null tests as well as interval (equivalence) tests on a simple, two independent samples setting. Interestingly, for interval tests our ROS analysis finds that Bayes factors suffer from an undesirable bias towards the equivalence hypothesis. We argue that other methods such as the Bayesian highest density interval (HDI) with region of practical equivalence (ROPE) or its frequentist analogue (confidence interval with ROPE) do not show this bias and might be preferable. With that, we demonstrate the diagnostic value ROS can have and hope that — due to its general applicability to any test — it will find its way into researchers' statistical toolboxes.

Unraveling Overreaction in Expectations: Leveraging Cognitive Sampling Algorithms in Price Prediction Tasks

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Session:
MathPsych Posters

When making financial forecasts, individuals often tend to overreact to recent information. This phenomenon has been consistently observed in both laboratory studies involving naïve participants (Afrouzi et al., 2023: https://doi.org/10.1093/qje/qjad009) and professional consensus real-world forecasting (Bordalo et al., 2020: https://doi.org/10.1257/aer.20181219). Leading models attribute this overreaction to either an overestimation of recent information or memory constraints favoring more accessible information. An alternative explanation posits that individuals accurately integrate all available information into the posterior probability distribution for forecasting. However, a key challenge arises from the inability to directly access this posterior distribution, leading forecasters to depend on approximation methods, such as sampling. Local sampling algorithms, supported in other forecasting contexts (Spicer, et al., 2022: https://doi.org/10.31234/osf.io/fjtha), may introduce overreaction due to the starting point bias, as well as greater variability in predictions due to their stochastic nature. Here, we leverage these phenomena to discern between competing explanations for the observed forecasting behaviour.

By reanalyzing data from a lab prediction task using a random walk price series (Afrouzi et al., 2023), we observe increasing variability in predicted values and forecast errors as the horizon expands, in keeping with sampling explanations. This data only offers a single prediction at each horizon, however; to further explore within-individual variability, we present a new experiment where participants are asked to repeatedly predict the same future value and use the results to distinguish between models.

Statistical Properties of Lens Model Equation Parameters and their Hierarchical Extension

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Session:
MathPsych Posters

The lens model equation builds on the Brunswik lens model and decomposes judgmental achievement (i.e., the correlation between judgments and true criterion values) into several correlational parameters. One of these parameters, the (linear) matching parameter G, is commonly used as an indicator of the extent to which individuals utilize the available environmental cues according to their respective validity to form a judgment. However, because G denotes the correlation between predicted values of two linear regression models containing the same set of predictors, it exhibits some undesirable statistical properties, such as a bias toward high values and a dependence on the number of cues, as first pointed out by Castellan (1973, Psychometrika). Since the G-parameter, despite its statistical limitations, remains a widely used tool in many fields of judgment research, we propose a hierarchical equivalent to address its limitations. We compare the statistical properties of the conventional G-parameter to its hierarchical equivalent in different simulation scenarios and in application to empirical data from metamemory research. Our results suggest that the hierarchical G estimator is more robust to misspecifications of the regression models, for example, due to unknown cues or item-cue interactions, and leads to more reliable estimates due to hierarchical shrinkage. We discuss that while G may not be a psychologically meaningful measure in all task environments, the hierarchical equivalent leads to more accurate estimates in judgment scenarios where G can be considered a sensible measure of matching accuracy.

Disentangling memory interference and motivational processes: A non-stationary diffusion/fast-guess mixture model for output interference in recognition memory

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Session:
MathPsych Posters

Memory performance declines over the course of a memory test, a finding referred to as output interference. A promising way to disentangle memory interference and motivation as underlying mechanisms is by means of the drift diffusion model (DDM). The DDM is a cognitive model for analyzing response time and choice data from binary decision tasks. Previous applications in the context of output interference focused on the development of drift-rate and boundary-separation parameters to measure changes in retrieval and motivation, respectively. However, motivation could also affect participants' tendency to engage in fast guessing instead of a more effortful cognitive process as measured by the DDM. Moreover, parameter development is typically analyzed across trial blocks rather than single trials. To address these limitations and (a) disentangle guesses from informed responses and (b) estimate parameter trajectories on a single-trial level, we used neural superstatistics, an emerging method for inferring parameter trajectories from empirical data, to estimate a non-stationary diffusion/fast-guess mixture model. The model was fitted to empirical recognition memory data from forced-choice and yes/no categorization tasks. We found that, while drift rate and boundary separation decrease over the course of the experiment, the probability to resort to fast guessing increases as well. These results emphasize the importance of accounting for guessing when analyzing output interference in recognition memory and highlight the usefulness of non-stationary cognitive models.

Simulation-based inference using deep neural networks: Using BayesFlow for amortized bayesian estimation of the diffusion model for conflict tasks

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Session:
MathPsych Posters

The congruency effect, characterized by faster reaction times in congruent trials compared to incongruent ones, is a consistent finding in various conflict tasks. Despite being considered a reflection of consistent cognitive abilities like inhibition or attentional control, inconsistencies in delta function trajectories and performance correlations across tasks present significant challenges. To address these limitations and to identify underlying processes using computational modeling, the Diffusion Model for Conflict Tasks (DMC) has been developed, showing promising predictions of different shapes of delta functions. However, estimating DMC parameters using traditional methods is challenging due to its intractable likelihood, leading to extensive computational effort. In this study, we used BayesFlow, a simulation-based approach that leverages deep neural networks, to overcome these challenges. BayesFlow approximates the underlying likelihood function from simulated data and generates a posterior probability distribution by employing two neural networks. It offers an extremely efficient approach, since, after training the networks, the parameter estimation is completed in real time. We conducted a simulation study to assess the capability of BayesFlow to recover simulated parameters. The implementation showed reasonable simulation-based calibration, sensitivity, and goodness-of-fit. The estimation of DMC parameters achieved excellent recovery, with correlations between simulated and recovered parameters ranging from r = .88 to r = .99, exceeding those of existing estimation techniques.

Associative priming and categorical priming in the word-picture paradigm: A hierarchical diffusion model analysis

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Session:
MathPsych Posters

Semantic priming has been intensively investigated in the lexical decision task, naming task, and semantic categorization task. Although semantic categorization task with short SOAs is considered to exclude strategic expectancy mechanisms and post-lexical processes, the category congruence effect is likely to confound semantic priming in this task. The study aims to disentangle semantic priming and category congruence effects in the semantic categorization task. We tested these effects by presenting prime and target as different modalities (i.e., prime as word and target as pictures). Specifically, we varied whether the primes were semantically associated with the targets and whether primes and targets belong to the same category (i.e., living/ non-living). We plan to use Bayesian hierarchical diffusion modeling analysis to test these hypotheses: Firstly, whether there is automatic spreading activation in this task with the cross-modal paradigm, which was often found mapping at drift rates in diffusion modeling. Secondly, whether there is a response competition or head start, which should be mapped on non-decisional times. Moreover, whether there is a decision bias (a bias at the starting point) in category compatible condition, which is also plausible to explain the category congruence effect. Models selectively manipulating these effects will be compared to test hypotheses.

Modelling probability matching as a Bayesian sampling process

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Session:
MathPsych Posters

Probability matching is a bias in human decision making, where people asked to choose between options with unequal probabilities sub-optimally 'match' the frequency of their responses to that of underlying events. Intriguingly, this effect is observed when subjects are not given any information about these probabilities, as well as when they are informed in advance.
We investigate whether probability matching can be the result of local sampling from an approximated distribution. Local sampling offers a unifying account for various biases and characteristics of human probabilistic judgements. Previous work has shown independent sampling captures global probability matching patterns. However, independent sampling ignores serial dependencies and often fails to account for nuances of behaviour. We explore the extent to which local sampling can improve on these results, and how it compares to competing explanations.
We designed an online experiment (N=147), describing to participants a six-sided die with four sides of one colour and two sides of another. Subjects then had to perform three variations of a binary choice task, as a counterbalanced within-subject factor. Two of them involved predicting the next outcome in a series of die rolls, with and without feedback. In the third task participants were asked to construct sequences of die rolls, one at a time, by mentally simulating the process.
We compare local sampling algorithms with several other quantitative models in their ability to account for characteristics of participants' behaviour in these tasks, such first-trial responses, serial dependence effects, and reaction times.

Inhibitory Control Deficits in Syndromes Associated with Frontotemporal Lobar Degeneration

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Session:
MathPsych Posters

Disinhibition is a prominent feature of syndromes associated with frontotemporal lobar degeneration (FTLD), encompassing impulsive behaviours and difficulty suppressing inappropriate or habitual responses. Being disinhibited in these syndromes has been linked to higher caregiver burden, earlier institutionalisation, and poorer prognosis (Murley et al., 2021). There are currently no treatments for disinhibition in FTLD. However, an avenue for potential treatment is that of neurotransmitter deficits. Gamma-aminobutyric acid (GABA) and noradrenaline deficits in FTLD are well established and are correlated with disinhibition (Murley et al., 2020; Ye et al., 2023). To develop and validate treatment strategies for disinhibition, we need to understand the delicate balance of neurotransmitter deficits in these syndromes and their link to disinhibition.

Here we use a manual stop-signal task to quantify inhibitory control in Progessive Supranuclear Palsy (PSP, Richardson's syndrome, n= 5), behavioural variant frontotemporal dementia (bvFTD; n = 9) and age- and sex-matched healthy adults (n=14). The stop-signal task is a well-established tool to quantify inhibitory control, with trans-species and trans-diagnostic utility.

We confirm that patients with PSP and bvFTD are impaired on the stop signal task (SSRT; M = 301.38, SD = 98.87) compared to controls (M = 187.38, SD = 32.78, p = 0.0003). Ongoing work is analysing the contribution of GABA-ergic and noradrenergic deficits to these deficits in inhibitory control.

Understanding the variance of inhibitory control has implications for timing of symptom onset, prognostication, and the development of pharmacological interventions to mitigate the behavioural challenges faced by affected individuals and their caregivers.

Change of Mind and Information Seeking in Decision Making

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Session:
MathPsych Posters

This research delves into decision-making, examining the effect of information seeking on the propensity to change one's mind. It also aims to differentiate between two metacognitive states: "believe I can know" and "don't believe I can know." Additionally, the study investigates whether beliefs in knowledgeability and the act of changing one's mind are associated with specific neural markers, thereby exploring the relationship between information seeking and change of mind

The methodology involves a color judgment task where participants are initially required to respond as quickly as possible. In some trials, they are given the opportunity to seek more information before reporting their final decision along with their confidence level. The results have shown different behavioral patterns in the change of mind under various information seeking scenarios, suggesting a significant role for information seeking in decision-making processes. Furthermore, decoding analysis of EEG data has demonstrated the ability to distinguish between the two metacognitive states at an individual level. These findings offer valuable insights into the underlying cognitive processes involved in information seeking and change of mind.

Using a shifted Wald model to assess the influence of cross-modal load on decision-making

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Session:
MathPsych Posters

When one attempts to multi-task, performance decreases, even for cross-modal (aural) working memory (WM) and (visual) search (VS) tasks. In this work, we investigate how the underlying decision-making (DM) processes change as a function of crossmodal multi-tasking and cognitive load. Specifically, we use a shifted Wald model to assess one's drift, i.e., the rate at which evidence is accumulated, and threshold, i.e., the amount of evidence needed to make a decision, in a 2-alternative force choice (2AFC) VS task and a single-bound (go/no-go) WM task (n-back) of various difficulties (1-,2-,3-back); each in isolation and in dual-task contexts. We capture parameters for each task, for each single task and multi-task condition at each cognitive load (1-,2-, 3-back). At the group-level, we find one's drift rate increases and threshold remains constant in the VS task, but only in the presence of a 1-back task; in context of a 2-/3-back task, drift (slight) and threshold (large) increase. In the n-back task, both drift and threshold decrease as the difficulty of the n-back increases and, except for 3-back, decrease even more in context of the VS task; however, this is at the cost of accuracy, and only correct response times were investigated using the shifted Wald model. In the 3-back task, parameters slightly increase when attempting to dual-task, compared to an isolated context. We discuss the feasibility of utilizing the shifted Wald for 2AFC and go/no-go tasks and discuss individual differences in the impact of cognitive load on parameters of DM.

The asymmetry between symmetry and asymmetry

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Session:
MathPsych Posters

The asymmetry between symmetry and asymmetry
Some have argued that symmetry is a core feature in visual perception. In a previous study, we found change detection was facilitated when a change from asymmetry to symmetry was an incidental cue. In the current study, our goal was to investigate whether that increased efficiency holds when a change from symmetry to asymmetry is an incidental cue. Participants were asked to judge whether the orientation of two lines may change in a way that preserves asymmetry or in a way that creates symmetry. For trials with pairs of lines, the lines create symmetry or asymmetry as an incidental feature. We applied the capacity coefficient, a tool from system factorial technology, to assess performance. The capacity coefficient gives both categorical results, whether there is a cost, benefit, or no change when two lines are used together, and quantitative results that could be used for examining individual differences. In previous study, we found all participants were super capacity when detecting a change from asymmetry to symmetry using the single-target-self-terminating (STST) capacity coefficient. In the current study, it was far less likely that participants demonstrated super capacity when there was an incidental change from symmetry to asymmetry, again using STST capacity. For comparison, in the previous study, when a change in symmetry was not an incidental cue (i.e., both reference and probe were symmetric) participants were generally around unlimited capacity but in the current study participants were limited capacity in the analogous trials (i.e., both reference and probe were asymmetric) based on the OR capacity coefficient.

Perception of Color Change Given a Set of Stimuli Across Specified Backgrounds

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Session:
MathPsych Posters

Color perception is highly dependent on the perceived context of the color, as demonstrated in the viral discussion surrounding, “The Dress.” One critical practical concern is that even when just a small band of color is blocked, it can influence the perception of a much wider range of colors. Due to a spate of incidents in which pilots were temporarily blinded by green laser pointers aimed at their aircraft from the ground, psychophysical research has been examining the direct effect laser eye protection (LEP) on pilots’ perception of information presented in colors near to the filtered range. Our current research examines how the perception of color in the context of other colors is affected by LEP. Participants observed four shapes at a time, each of which is has a distinct solid-color background. One of the shapes is filled with a slightly different hue than the other three, and the participant’s task was to indicate which shape was a different color. To calibrate for individual color perception, the task begins with an adaptive phase, to determine the level of hue change. Then, participants go through a control phase, and a phase with LEP to compare accuracy. The data collected indicates that accuracy is decreased when presented with red and green shapes across desaturated backgrounds and increased when presented with blue and yellow shapes across extremely saturated backgrounds.

Studying how visual clues affect navigation and mental mapping in Virtual Reality

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MathPsych Posters

Knowing evacuation routes can save lives during disasters. Therefore, it is important to optimize them. This work aims to improve emergency exit route design in situations like earthquakes or fires. We utilized Virtual Reality (VR) to design mazes with varying difficulty levels (easy and hard) and visual cue types (colors and objects), to examine their impact on the visual search time and recall abilities of participants (N=20). Participants completed memory and cognitive tasks before navigating the mazes in two separate trials, one with and another without instruction. The study employed a fractional factorial experimental design considering factors: gender, dominant hand, and types of visual cues, to study their influence in two maze difficulty levels. Our finding suggests that Gender, the difficulty, and the interaction of Gender and Visual cue type have a statistically significant effect on the average time users spend at each tile. We further analyzed if the effect of Gender can be explained by spatial abilities. However, gender remained a statistically significant factor in navigation performance. Also, we developed the first GOMS model in VR and analyzed the method's longest completion time. Findings from this research can assist VR designers in creating inclusive user-friendly interfaces alongside real-world applications, such as more effective emergency exit routes in interior designs, potentially saving lives during disasters.

Comparing the impact of medical image classification training on human and machine representations

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Session:
MathPsych Posters

How does category learning, such as medical image classification tasks, change mental representations? Is the change in mental representations similar to the change in neural network representations when trained on specialized tasks? In this project, we compare similarity obtained from neural network representations to human similarity representations before and after they both were trained to classify white blood cell images into blast (cancerous) and non-blast (non-cancerous) categories. We focus on the two neural network representations for each image: (i) pretrained GoogLeNet on ImageNet (Stock Representation), which has not received training on white blood cell classification and (ii) GoogLeNet trained on cancer cell classification (Task Representation) using transfer learning following Holmes et al. (2020). Using each neural network representation, we calculate the similarity between two images as the Euclidean distance between the image embeddings. We also conducted an experiment where we recruited human participants from MTurk using CloudResearch. We probe human representations by eliciting similarity judgments on carefully curated pairs of images before and after they learn to classify the cancer cell images. We draw comparisons between human and artificial neural network representations and discuss the implications for medical image training.

Investigating the belief bias in everyday political reasoning with linear models and signal detection models

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Session:
MathPsych Posters

The belief bias describes the phenomenon that, when asked to judge the validity of a logical argument, people are influenced by the believability of the argument's conclusion.
We investigated the belief bias in the context of everyday arguments regarding controversial political topics like those found on (social) media. Arguments differed in their (informal) argument quality; 'good' arguments provide strong evidence for their conclusion, whilst 'bad' arguments provide only weak evidence. Participants rated their beliefs about a series of political claims (e.g., 'abortion should be legal') on a 7-point Likert scale and rated the strength of good and bad arguments about these claims. In Experiment 1, participants rated argument strength on a scale of 1 (extremely bad argument) to 6 (extremely good argument), while in Experiment 2 they rated it on a binary scale (i.e., either bad or good). We analysed both experiments using linear models and probit models, i.e., equal variance signal detection models. In both experiments, with both types of models, we found a belief bias for everyday arguments. Participants thought the quality of good arguments was stronger than the quality of bad arguments, but also perceived arguments in line with their beliefs as better than arguments that were not. Furthermore, independent of the model used, we found no evidence for an interaction between belief and argument quality.

Social Network Analysis of People Occurring in a Long Series of Dreams

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Session:
MathPsych Posters

People in dreams arise from the dreamer's semantic memory of people and their relations. If memory is veridical, properties of people in dreams would reflect properties of waking social life. A man recorded people occurring in his dreams for 32 years. We report two comparisons with waking life. First, appearance of a person in a dream is analogous to contact with that person in waking life. Saramäki, et al. (2014) found properties of contacts individuals made by mobile phone over successive time intervals. (a) A small number of people receive a large fraction of calls. (b) There is turnover of people over intervals, with higher retention for higher frequency people. (c) The shape of an individual's distribution of frequencies of calls to people has some variation, but despite turnover tends to persist in time. The properties were found in frequencies of people occurring in the dreams. Second, waking life social networks tend to have a power law degree distribution and the small world combination of high clustering with short distances between vertices. For each year, a dream social network was made by representing each person by a vertex and joining two vertices with an edge if they cooccurred in a dream. A power law fit the degree distributions well and the Small-World Propensity was at the upper limit of 1. Occurrences of people in dreams have properties like those in waking life, although there are changes over time, for example, a slight decrease in distances between vertices.

Guess what! Assessing the psychological meaning of the Lévy-flight model parameter α

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Session:
MathPsych Posters

According to the diffusion model (Ratcliff, 1978), binary decisions stem from a process of continuous evidence accumulation with normally distributed noise. The Lévy-flight model (Voss et al., 2019) extends this framework by introducing the parameter α, which modifies the noise distribution. Specifically, lower α-values result in heavier tails of the noise distribution, leading to more frequent sudden large changes (i.e., jumps) in evidence accumulation. While α can enable a superior fit to the data, its psychological meaning remains empirically underexplored. Therefore, we examined whether α reflects guessing, predicting a decrease in α-values as individuals are prompted to guess. In our experiment, participants performed a brightness discrimination task under two conditions, each emphasizing a different approach to decision-making: In the guessing condition, we instructed participants to take an educated guess when in doubt. In the control condition, we instructed participants to only select an answer once they felt confident about their choice. Given that the modified noise distribution makes the likelihood of the Lévy-flight model intractable, we employed the BayesFlow framework, leveraging its simulation-based deep learning capabilities for our analyses. Contrary to our expectations, the difference in α between the two conditions did not reach statistical significance, possibly due to the high difficulty level of the employed task. Accordingly, we advocate for and delineate further inquiries of possible interpretations of α, particularly regarding guessing.

Fast Likelihood Computation for Attentional Drift Diffusion Models and Beyond

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Session:
MathPsych Posters

Classical versions of sequential sampling models (SSMs) assume that the rate of accumulation is constant over a given trial. Empirical evidence however suggests that instead, moment by moment attention, indicated for example by eye gaze patterns, can shift the rate of accumulation such that it vacillates over the course of single trials. These dynamics are captured by models such as the attentional Drift Diffusion Model (aDDM). However, parameter inference for such models, in a way that faithfully tracks the generative process, remains a challenge. Specifically, the attention process, captured as arbitrary saccades and gaze times, forms a time-point-wise covariate which can't be reduced to a fixed dimensional summary statistic, and thus poses a challenge even for likelihood-free methods on the research frontier.
We propose a method for fast computation of likelihoods for a class of models which subsumes the aDDM. The method divides each trial into discrete time stages with fixed attention, uses fast analytical methods to assess stage-wise likelihoods and integrates these to calculate overall trial-wise likelihoods. Operationalizing this method we characterize parameter recovery in a variety of settings and compare to widely used approximations to the aDDM, which instead only use fixation proportions to maintain tractable likelihoods. We characterize the space of experiments in which such approximations may be appropriate and point out which settings drive model formulations apart. Our method will be made available to the community as a small python package, which will integrate seamlessly into a wider probabilistic programming ecosystem around the PyMC python library.

ASSM: A Python package for Bayesian parameter estimation of attentional sequential sampling models

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Session:
MathPsych Posters

The role of visual attention in perceptual/preferential decision-making has been established over the decades. Hence, several computational models based on sequential sampling theory (e.g., attentional drift-diffusion model (aDDM), gaze-weighted linear accumulator model (GLAM), or gaze-advantage race diffusion model (GARD)) have been proposed to account for visual attention in the accumulation process. These computational models are quite successful in explaining the role of visual attention in the accumulation process and have been used in different domains. However, only a few computational packages are developed to estimate the parameters and fit these models on empirical data. 'ASSM' is a Python package that provides a hierarchical Bayesian parameter estimation framework for attentional sequential sampling models. This package is developed based on Stan and includes different versions of aDDM, GLAM, and GARD models (e.g., uni-attribute/multi-attribute) with different attentional mechanisms. Moreover, 'ASSM' supports both individual- and group-level fitting procedures for these computational models and accommodates empirical data collected from 2-alternative or multi-alternative decision tasks.

Reimagining Security with Cyberpsychology Network Defenses (ReSCIND)

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Session:
MathPsych Posters

The Intelligence Advanced Research Projects Activity (IARPA) — the research and development arm of the U.S. Office of the Director of National Intelligence — in January 2024 launched an innovative program that, for the first time, takes aim at the psychology of a cyber attacker.

The goal of the Reimagining Security with Cyberpsychology-Informed Network Defenses (ReSCIND) Program is to leverage a cyber attacker's human constraints, such as innate decision-making biases and cognitive vulnerabilities, to disrupt their attacks. While attackers take advantage of human errors, most cyber defenses do not similarly exploit the attackers' cognitive weaknesses — ReSCIND strives to flip this paradigm. By combining traditional cybersecurity practices with the emerging field of cyberpsychology, IARPA is set to engineer this first-of-its-kind cyber technology that makes an attacker's job that much harder, by focusing on the human behind the attack.

The design of novel defense capabilities will be grounded by foundational science and the effectiveness quantified with rigorous experimentation and analysis. Experimental analysis results will be utilized to iteratively improve and model these cyberpsychology-inspired methods to impact attackers (e.g., causing frustration, surprise, choice overload, or risk aversion). Features such as the target network, attacker profile, and inferred attacker goals that can help predict and induce attacker mistakes and irrational behavior will be identified and incorporated into the defensive capabilities. Cultural aspects, operational tempo, motivation, and other specifics of real-world cyber campaigns will be critical considerations for experimental designs and modeling efforts.

Approximating an Exact Posterior for the Drift-Rate Parameter of a Wiener Process's First-Passage Time

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Session:
MathPsych Posters

In cognitive psychology, simple response times are often modeled as the time required by a one-dimensional Wiener process to first reach a given threshold. This stochastic process's first-passage time follows a Wald distribution, which is essentially a reparametrized inverse-Gaussian distribution. Since the inverse-Gaussian distribution is part of the exponential family, there must exist a conjugate prior with respect to such a data-generating process. It can be shown that the Gaussian-Gamma distribution satisfies the conjugacy property, albeit under a parameterization different from that of the Wald distribution. This leads to a posterior distribution that does not directly correspond to the core parameters of the Wiener process; that is, the drift-rate and the threshold parameter. While the marginal threshold posterior under a Gaussian-Gamma prior is relatively easy to derive and turns out to be a known distribution, this is not the case for the marginal drift-rate posterior. Here, I addresses this issue by providing the exact solution for the marginal posterior distributions of the drift-rate parameter under a Gaussian-Gamma prior. Unfortunately, the probability density function of this distribution cannot be expressed in terms of elementary functions. Thus, different methods of approximation are discussed as an expedient for time-critical applications.

The Contiguity Effect in Probed Recall Task: Increasing the Recall via Overt Rehearsal and Sentence Generation

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Session:
MathPsych Posters

The contiguity effect is the finding that when an item is recalled, the next item to be recalled is inclined to come from neighbouring study positions to the position of the just recalled item. In the recall literature, the contiguity effect is observed with a forward asymmetry. Various models have been developed to account for the contiguity effect. Kılıç et al. (2013) offered two classes of models: Causal models such as the Temporal Context Model (TCM) suggest that when an item is recalled, it causes another item to be recalled due to the recalled items' study context being incorporated into the test context, whereas according to non-causal models, the context in the study changes independently of the items and this study context is reiterated during the test phase. Kılıç et al. (2013) employed the probed recall task to disrupt this supposed reiteration. They observed a contiguity effect but not the forward asymmetry, which was attributed to low recall performance. In the current study, we aimed to increase the recall performance to decide whether the lack of asymmetry indicates the contribution of non-causal mechanisms or low performance. Therefore, the probed recall task was utilized along with overt rehearsal and sentence generation tasks during the study phase to increase recall performance. At the test, probe words were given and another word from the list of the probe words was requested. Conditional Response Probability (CRP) analysis revealed within and between-list contiguity effects, but the results did not show a forward asymmetry.

Response-time extended multinomial processing trees with diffusion-model kernels

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Session:
MathPsych Posters

We updated the R package "rtmpt" with a newly developed method to incorporate response times in the class of multinomial processing tree (MPT) models. Like the method implemented in the previous version of the package, this new method allows for the estimation of process-completion times as well as process-outcome probabilities. However, in contrast to the previous method, in which each process-completion time was assumed to follow an exponential distribution, it assumes that these quantities are determined by the outcome of a Wiener diffusion process. Consequently, the process completion times no longer possess the questionable memoryless property. In addition, the new method can account for non-monotonic hazard rates of a single processing branch. Both of these characteristics make the new method more realistic in view of actual response times. Furthermore, a comparison of both approaches can serve as a means to perform robustness checks with respect to the auxiliary assumptions regarding process kernels. We show how to use the new method and demonstrate the validity of the underlying hierarchical Bayesian MCMC algorithm via a simulation based calibration.

Diffusion Models for Conflict Tasks: Revisiting the Revised Diffusion Model for Conflict tasks (RDMC)

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Session:
MathPsych Posters

In conflict tasks, such as the Simon, Eriksen flanker, or Stroop task, a relevant and an irrelevant feature indicate the same or different responses in congruent and incongruent trials, respectively. The congruency effect refers to faster and less error-prone responses in congruent relative to incongruent trials. Distributional analyses reveal that the congruency effect in the Simon task becomes smaller with increasing RTs, reflected by a negative-going delta plot, whereas for other tasks, the delta plot is typically positive-going, meaning that the congruency effects become larger with increasing RTs. The Diffusion Model for Conflict tasks (DMC; Ulrich et al., 2015, Cognitive Psychology) accounts for this by explicitly modelling the information accumulated from the relevant and the irrelevant features and attributes negative- versus positive-going delta plots to different peak times of a pulse-like activation of the task-irrelevant feature. Recently, Lee and Sewell (2023, Psychonomic Bulletin & Review) questioned this assumption and advanced their Revised Diffusion Model of Conflict tasks (RDMC). We address three issues regarding RDMC in comparison with DMC: (1) The pulse-like function is not as implausible as Lee and Sewell suggest. (2) RDMC itself comes with the highly implausible assumption that different parameters are required for congruent and incongruent trials. (3) According to a new parameter recovery study, RDMC lacks acceptable recovery (in particular compared to DMC). Against this background, we do not see an advantage of RDMC over DMC at present.

Testing Random-Scale Representation in Change Detection Tasks for Visual Working Memory

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Session:
MathPsych Posters

Long-term memory (LTM) and working memory (WM) are considered distinct memory components. This assumed difference is also reflected in different experimental tasks (e.g., recognition vs change detection tasks). However, there is as of yet no clear empirical evidence delineating what makes a task require LTM or WM. Recent work by Kellen et al. (2021, Psychological Review) established empirically that the general class of signal detection theory (SDT) models underlies recognition-memory judgements in LTM. A central feature of this model class is that it assumes unlimited capacity, which conflicts with one of the central assumptions regarding the structure of WM, that WM is capacity limited. The present work examines whether recognition judgements in visual WM satisfy the Block-Marschak (BM) inequalities. Satisfying the BM inequalities implies a random-scale representation, the key property of the SDT model class. In several experiments we find that performance in visual WM change detection does not satisfy BM inequalities. This finding implies that a random-scale representation does not hold for visual WM. However, when using the same stimuli as typically used in visual WM task in a LTM task, we replicate earlier results that LTM judgements satisfy the BM inequalities. Considering that the concept of capacity limits in WM is fundamentally at odds with the assumptions that underly random-scale representation, our result that visual WM judgements do not satisfy the BM inequalities is maybe unsurprising but nevertheless provide a first foray into establishing a strong empirical distinction between LTM and visual WM.

dRiftDM: An R package for Fitting Diffusion Models with Time-Dependent Parameters

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Session:
MathPsych Posters

In many areas of psychology and neuroscience, drift-diffusion models (DDMs) have become an important framework for understanding decision processes. Models in this framework assume that response information accumulates in an incremental but noisy manner until a threshold is reached. To date, several software packages exist to fit DDMs, ranging from more classical packages such as fast-dm (Voss & Voss, 2007, BRM) or ez (Wagenmakers et al. 2007, PBR) to modern Python packages such as pyddm (Shinn et al., 2020, eLife) or PyBEAM (Murrow & Holmes, 2023, BRM). However, many of these packages are either limited to time-invariant parameters or require knowledge of Python. Here we present the dRiftDM package, an R package for fitting DDMs with time-varying parameters. The package uses a numerical approximation of the Kolmogorov forward equation to fit DDMs via maximum likelihood. The dRiftDM package is designed to be easy to use and with the typical requirements of psychological researchers in mind. For example, we provide straightforward functions for fitting and loading data sets, exploring model properties, or performing model comparison. dRiftDM can be used flexibly to implement a wide range of DDMs. In addition, it already provides pre-built models that are common in cognitive psychology. By making it easy to apply DDMs in R, dRiftDM is a valuable tool that provides researchers with an entry point to a model-driven approach to their data.

Utilizing response time assessments of cognitive function: The first step in understanding cancer-related cognitive impairment

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Session:
MathPsych Posters

Oncology professionals rely on self-report questionnaires to assess cognitive function throughout cancer treatment. This has proven problematic, as inconsistent and contradictory results have hindered the ability to measure the nuances of cognitive dysfunction. In turn, researchers have struggled to pinpoint the true underlying cause of cancer-related cognitive impairment amongst the array of possible sources. We believe that by utilizing the partitioning, highly sensitive capabilities of response time modeling in cognitive assessments, we will be able to encapsulate cancer-related cognitive impairment more accurately. By studying response time model trends across assessments of biomarkers, we aim to evaluate the possibility of immune response playing a causal role in cognitive dysfunction. The purpose of the current study was to establish a baseline understanding of the typical function associated with our assessment task and perform a power analysis to determine the necessary number of trials that will ensure as accurate of response time parameters as possible. The cognitive assessment tested in this project was the dual-n-back test. This task challenges participants to remember a string of auditory and visual stimuli, allowing researchers to test the capabilities and limits of working memory, one of the main areas of cognition impacted by cancer-related cognitive impairment. We believe that the current study's quantitative approach will elucidate components of the underlying cognitive mechanisms involved in working memory, through the workload capacity metric. This study served as an important first step in understanding and measuring the complexities of cancer-related cognitive impairment.

A New Frontiers For Affect Dynamics: The Discrete Markovian Chain Of Affect

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Session:
MathPsych Posters

Affect dynamics, or the study of changing patterns of emotional experiences throughout time, has developed as an important area of research in Mathematical Psychology. Traditionally, Affect Dynamics analysis has used the Experience Sampling Method (ESM), a data collection approach in which participants report their feelings, thoughts, and behaviours at various periods during the day. This approach models Intensive Longitudinal data (ILD) using Mixed Linear or nonlinear Models (MLM) or Vector Autoregressive Models (VAR). These models define emotion in terms of temporality and complexity. However, they overlook the fundamental unity of affective dynamism: the transition between states. Although emotions occur in sequential order, the transition between them considers the prior state in relation to the present one. Individuals can feel and describe numerous emotions at the same time, but one emotion usually takes precedence, influencing or being compared to the prior one. In this work, we want to employ discrete Markov chains to assess each transition between the prior and present emotional states, disregarding earlier transitions in the same manner that a Markov chain does. Indeed, Markov chains are mathematical systems that represent a succession of potential occurrences, with the probability of each event determined solely by the state obtained in the preceding event. Here, we present an empirical study that used self-reported emotional responses and physiological data (heart rate variability, face electromyography, and galvanic skin reaction) to create a discrete Markov chain and compare it to autoregressive models.

Can Variability in Across-Trial Drift Rate be Explained in the Diffusion Decision Model?

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Session:
MathPsych Posters

An assumption of the "full" diffusion model is that the rate of evidence accumulation varies across trials, which can account for slow errors and asymptotic accuracy (Ratcliff, 1978). This assumption has been criticized by researchers as an ad hoc addition to the model that adds additional flexibility to the model. In the present work, we ask whether linking the drift rate to systematic experimental factors can mitigate the need for a drift rate variability parameter. Using a recognition memory dataset with electroencephalography (EEG) recordings (n = 132), we systematically linked drift rate to individual trials using exogenous experimental factors – such as word frequency and study-test lag– along with endogenous factors using EEG data. We expected that the inclusion of such factors would reduce the estimates of the drift rate variability parameter. We first demonstrated the feasibility of this modelling approach with simulated data. However, counter to this prediction, with experimental data, model fits indicated that the inclusion of systematic variability resulted in little decrease in the random drift rate variability parameter. This suggests that the implementation of a normal distribution of drift rate can be hard to meaningfully interpret in practice, and that other mechanisms might be involved in producing slow errors which are not implemented in DDM.

A Spectrum of Diffusion Models for Hierarchical Control of Attention: From Sequential to Parallel Processing

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Session:
MathPsych Posters

Sequential Sampling Models (SSMs) are ubiquitously applied to empirical data of two or more alternative choice tasks, subsuming a large variety of task paradigms. Nevertheless the space of models typically considered is often limited to those that are analytically tractable for inference. More recently the field of simulation based inference has enabled the development and evaluation of a much broader class of models. Here we leverage developments in likelihood free inference using artificial neural networks in order to evaluate a range of models applied to a hierarchical decision making task.

Participants were presented with stimuli, in the form of lines that varied across three dimensions: movement direction, line orientation and color. These three features imply three potential decisions (dominant motion direction etc.) on a given trial. One feature was considered the 'high-dimension', and determined which of the remaining two 'low-dimensional' features were relevant for a given choice scenario. The task is therefore hierarchical, in that the high dimensional features acts as a filter on which one of two remaining tasks a subject needs to solve.

To investigate the corresponding cognitive strategies used by participants to solve these tasks, we developed a range of diffusion model variants to assess whether participants accumulate evidence strictly hierarchically and therefore sequentially, in parallel, or via a hybrid resource rational approach. We will assess model fits and posterior predictive simulations to arbitrate between these accounts and to link them to trial-by-trial neural dynamics (via EEG) associated with encoding of higher and lower dimensional features.

Bias in Belief Updating: Combining the Bayesian Sampler with Heuristics

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Session:
MathPsych Posters

The systematic deviations from rational Bayesian updating of beliefs, such as conservatism and base-rate neglect, have been extensively studied. Two primary cognitive models have been proposed to explain these biases: simple heuristics (Woike et al., 2023) and stochastic sampling approximations of the Bayesian solution, such as the Bayesian Sampler (Zhu et al., 2020). However, recent research suggests that neither of these explanations fully accounts for observed behaviors. In a study by Stengård et al. (2022), only about half of participants' responses aligned with heuristics, indicating a gap between heuristic-based and Bayesian models. To address this gap, we propose exploring a new class of models that blend heuristics with Bayesian approaches. In our study, we investigate simple mixtures of heuristics and the Bayesian Sampler, as well as a hybrid model combining heuristics for setting priors and Bayesian methods for refining estimates using stochastic samples. Our analysis indicates that neither heuristics nor the Bayesian Sampler alone are sufficient to explain the observed data. Instead, a combination of these approaches appears to offer a more comprehensive explanation for human decision-making behaviors. By incorporating elements of both heuristic reasoning and Bayesian updating, our hybrid model shows promise in better capturing the complexities of human cognition and decision-making processes. Further research in this direction could provide valuable insights into understanding and potentially mitigating cognitive biases in real-world contexts.

Modeling Numerical Judgments of Complex Stimuli

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Session:
MathPsych Posters

Research investigating the processes of multiple-cue judgments usually relies on simple artificial stimuli with predefined cue structures, since the cognitive models used in this area of research require that the cue structure is known. Unfortunately, this hinders the application of these models to situations involving complex stimuli with unknown cue structures. Building upon early categorization research, in two studies we demonstrate how the cue structures of complex and realistic stimuli can be extracted from pairwise similarity ratings with a multidimensional scaling analysis (MDS) and then subsequently be used to model participants' quantitative judgments with a hierarchical Bayesian model. After an initial validation study, we use MDS to generate cues for complex stimuli with an unknown cue structure based on pairwise similarity ratings of N = 110 participants. These cues are then used in a hierarchical Bayesian model to analyze judgments of these complex stimuli from N = 80 participants. Our results replicate previous findings that demonstrate the influence of learning tasks and feedback on strategy selection in judgment tasks. This highlights the feasibility of our approach and extends the generalizability of previous findings to more complex stimuli.

Quantitatively fitting the Autocorrelated Bayesian Sampler to accuracy, response time and trial-by-trial data

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Session:
MathPsych Posters

The Autocorrelated Bayesian Sampler (ABS; Zhu et al., 2023) is a sequential sampling model that assumes people draw autocorrelated samples from the memory of hypotheses according to their posterior beliefs. Samples are then integrated to produce choices, response times, confidence judgments, estimates, confidence intervals, or probability judgments. For example, for forced choices samples are aggregated until those in favour of one response category exceed those in favour of the other, and then the favoured option is chosen. The ABS consists of two components: the mechanism of sampling and the response time distribution. Within this framework, we propose a novel ABS model integrating the MCREC sampling algorithm (Castillo et al., 2024) and a Gaussian response time distribution. We compared both ABS variants with the well-established and widely used Drift Diffusion Model (DDM; Ratcliff, 1978; Ratcliff & McKoon, 2008; Ratcliff & Rouder, 1998) to investigate the strengths and limitations of the ABS models. We fit three models to a random dot motion task data (from Murphy et al., 2014) using Approximate Bayesian Computation (ABC; Beaumont et al., 2002; Csilléry et al., 2010; Marin et al., 2012) to evaluate how well the models account for the data. Our comparison incorporates statistics such as accuracy rates, response time quantiles, and the probability of repeating past choices. Through this analysis, we aim to illustrate how differences in their assumptions and approaches affect their performance across varied contests, thereby identifying directions for enhancing the explanatory power of these models.

On the appropriate scale of time for psychophysical duration discrimination

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Session:
MathPsych Posters

Psychophysical data on duration discrimination are typically fitted via logistic or Gaussian psychometric functions. These functions are symmetric, with the consequence that estimates of the 25% and 75% points are forced to lie at the same distance from the standard duration albeit in opposite directions. This characteristic is at odds with Weber's law, which posits that the just-noticeable difference is proportional to the standard duration. Thus, if the proportionality factor were, say, 1.5, a duration of 300 ms would be just discriminable from a duration of 200 ms and a duration of 450 ms would be just discriminable from a duration of 300 ms. Put together, when the standard duration is 300 ms, points of equal discrimination performance below and above the standard should lie at different distances (in ms) from the standard, in contrast to what fitting symmetric psychometric functions renders. We conducted a simulation study that fitted psychometric functions to data generated to obey Weber's law, which essentially implies that the relevant scale for time is log duration instead of duration. The results show that fitting conventional psychometric functions (of duration in ms) misrepresents discrimination performance and provides erroneous estimates of the difference limen, whereas fitting asymmetric psychometric functions (of log duration) captures generating performance adequately. Psychometric functions of log duration generally fitted the data much better than psychometric functions of duration in ms, although the fit turned out similar in some cases. Some empirical data are presented that corroborate the validity of these simulation results.

The puzzle of order effects in duration discrimination

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Session:
MathPsych Posters

Order effects are a pervasive phenomenon in psychophysics. They manifest in some measure of discrimination performance differing with the order in which the stimuli to be compared (standard vs. test) are presented in each trial. Different types of order effects have been described that hold for a wide range of sensory modalities and stimuli, and many of them can be accounted for by a number of models of psychophysical performance. However, time perception seems to be fundamentally different and the origin of order effects observed in duration discrimination tasks remains undisclosed.

We conducted an experimental study using a duration discrimination task to collect data at different standard durations in the range of hundreds of milliseconds. Every dataset was then analyzed under different frameworks given by well-established models that can accommodate order effects: Indecision (https://doi.org/10.3389/fpsyg.2017.01142), Internal Reference (https://doi.org/10.3758/s13414-012-0362-4), and Sensation Weighting (https://doi.org/10.3758/s13414-020-01999-z). Psychometric functions derived from each model were fitted to the data both separately and jointly across presentation orders. All analyses were carried out twice, assuming either duration in milliseconds or log duration as the relevant scale for time perception. Our results provide a comprehensive map of order effects in discrimination of short durations and a solid analysis of the strengths and weaknesses of each model. Implications are discussed paving our way towards a better understanding of order effects in duration discrimination.

A two-drift race model of human habits

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Session:
MathPsych Posters

Psychologically, habits are defined as the reward-independent, stimulus-response relationships which form when identical actions are repeated often. These behaviours were originally studied in animals, and Hardwick et al. (2019) recently developed a paradigm to identify habits in humans. They hypothesised that human habits may be detected when participants are forced to act too quickly for conscious (goal-directed) control to be applied. They trained participants extensively on a stimulus-response mapping, and then the mapping was reversed. When participants were tested post-reversal, their behaviour changed depending on how rapidly they needed to react. Specifically, participants made more 'habitual' errors, i.e., choosing the original response, when forced to respond within 300-600ms. Hardwick et al. proposed that parallel accumulators were responsible, wherein the goal-directed system is initiated after a delay.

However, no formal mathematical model exists that instantiates this proposal and allows for multiple drift rates which change both across (via reinforcement learning) and within (parallel accumulators) trials.

In this paper, we present a novel 2-drift race model, and calculate the probability of reaction times and choices so it can be efficiently fitted to data from the paradigm by Hardwick et al.

To test their proposal, we compare the quality of fit of a single-drift Q-learn race model and that of our model, in which habit and goal-directed actions accumulate independently. Furthermore, the best fit parameters of the 2-drift model can provide several key insights into, and quantifiable measures of, the mechanistic structure underlying the differences between individuals' reliance on habits, undetectable in behaviour alone.

Amortized stochastic time series models for intervention designs

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Session:
MathPsych Posters

Interrupted time series analysis is a statistical method to study the effects of a deliberate intervention by observing data over a period before and after a change. In this project, we consider interrupted time-series data from a mobile health intervention study aimed at promoting psychological well-being in college students. We will apply a model for interrupted time series based on the Ornstein-Uhlenbeck (OU) diffusion model, a stochastic time series model whose main parameters capture intraindividual variability, an attractor point or homeostasis level, and an elasticity parameter that governs the speed with which the process returns to its attractor after a perturbation. Interruptions in these time series can be characterized as discrete state shifts in one or more of these parameters, leading to the hierarchical Bayesian interrupted OU model that we apply to the mobile health intervention. We evaluate the intervention's effectiveness by examining the levels of psychological well-being across four study phases: pre-intervention, intervention, immediate post-intervention, and late post-intervention. We operate under the assumption that we can categorize the time series according to these phases, anticipating that participants' psychological well-being tends to stabilize at specific homeostatic levels during each phase. Additionally, we evaluate the applicability of BayesFlow to this broader class of problem. BayesFlow is a new simulation-based inference method that can provide high-efficiency Bayesian parameter estimation even with complex, time-variant models, but its application to a multilevel hierarchical model such as ours requires a thoughtful implementation. We discuss strategies for our specific case and possible expansions of our work.

The crossed random effects drift diffusion model in social cognition research – a simulation study

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Session:
ICCM Posters

To properly capture interindividual variability in cognitive processes, cognitive modelers increasingly employ hierarchical Bayesian models in which subjects are treated as random effects. Additional random effects may be added to the model for stimuli, for example, when subjects are crossed with social target stimuli as in social cognition experiments (Judd et al., 2012). To date, few simulation studies have comprehensively investigated the estimation performance of such more complex hierarchical cognitive models. In our simulation study, we sought to close this gap for the crossed random effects variant of the Drift Diffusion Model (DDM; Ratcliff, 1978; Vandekerckhove et al., 2010). We used a simulation design with two crossed random effects - mirroring subjects and targets as in social cognition experiments - and we varied design settings in ways realistic to such experiments. Specifically, we manipulated the variance of subject and target population distributions, mirroring homo- vs. heterogeneous populations, as well as the number of draws from each population, mirroring subject and trial numbers. Additionally, we manipulated model complexity by inducing constraints on the estimated random effect structure (crossed vs. single vs. no random effects). All models were estimated in JAGS and their estimation was evaluated based on different performance criteria (e.g., bias). Importantly, performance evaluation considered both the individual and the population level for both subjects and targets, providing novel insights into the interplay of multiple random effects on cognitive parameter estimation across levels.

Exploring Memory Mechanisms Underlying the Continued Influence Effect

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Session:
ICCM Posters

Humans have cognitive vulnerabilities that can be leveraged to influence individuals. One such vulnerability is the continued influence effect (CIE), where misleading information can have a lasting effect even after corrections or factual discrediting information is presented. The CIE has been addressed experimentally and memory-based explanations exist. However, no current cognitive models specify cognitive mechanisms for prediction, simulation, and detailed testing of hypotheses. Here, we discuss relevant literature and propose a novel cognitive model to investigate memory mechanisms underlying the CIE.We demonstrate the utility of the model using simulations which show how the CIE emerges from memory processes and discuss plans for future research.

Computer-Based Experiments in VR: A Virtual Reality Environment to Conduct Experiments, Collect Participants' Data and Cognitive Modeling in VR

This paper explores the integration of Virtual Reality (VR) into behavioral experiments, addressing the technical challenges that researchers face due to the necessity of advanced programming and game engine knowledge. By developing a VR environment tailored for conducting computer-based experiments and pairing it with VR Analysis Tool (VRAT) for data analysis and visualization, we facilitate a more accessible entry into VR-based research. The advantage that our tool provides is that researchers can conduct their traditional computer-based experiments in an environment with superior eye tracking and high experiment validity due to a high level of control over environmental factors. We then showcase the advantages of VR eye-tracking systems over traditional screen-based counterparts in terms of accuracy and precision, highlighting their consistency across various screen sizes and user demographics which is only one of the many superiorities of VR over the conventional methods. Due to the applicability of the 3D design, we believe that the future of behavioral research will increasingly pivot toward VR, with tools like VisiTor pioneering this transition by enabling models to effectively interact within VR spaces. Our tool is a step toward enabling behavioral studies to immigrate from traditional methods to VR.

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Session:
ICCM Posters

Understanding Human Behavior and Cognitive Model in an Image Labeling Task

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The field of Artificial Intelligence (AI), particularly in the area of computer vision, has experienced significant advancements since the emergence of deep learning models trained on extensively large labeled datasets. However, reliance on human labelers raises concerns regarding bias, inconsistency, and ethical issues. This study aimed to address these concerns by exploring the feasibility of replacing human labelers with an interactive cognitive model. We investigated human behavior in a two-phase image labeling task and developed a model using the VisiTor (Vision + Motor) framework within the ACT-R cognitive architecture. This study was designed based on a real labeling task of identifying different crystals in optical microscopic images after various treatments for inhibiting the formation of the crystals. The outcomes from the image labeling experiment, which included both learning and testing phases, revealed meaningful observations. The observed decrease in task completion times for all participants during the learning phase suggests an increased familiarity with the image features, facilitated by the reference images presented in all four consecutive example tasks. During the testing phase, despite initial confusion caused by shaded zones in microscopic images, participants were able to correctly identify targets, highlighting the potential for cognitive models to learn and adapt. It was also discovered that the subtle distinctions between classes led to confusion in making decisions about labels. The developed interactive cognitive model was able to simulate human behavior in the same labeling task environment, while the model achieved high accuracy, it still relies on pre-defined features therefore limited its application to seen data only. Future work will expand the number of participants and task complexity and refine the ACT-R model to enhance its decision-making capabilities. Our findings suggest that interactive cognitive modeling offers a promising avenue for replacing human labelers with robust, consistent, and unbiased labeled datasets. This research can help mitigate ethical concerns and ultimately move us toward the goal of automating the labeling process in AI.

A Comparison of Frequency Effects in Two Attitude Retrieval Models

The psychological literature has put forth several auto-associative memory models of attitude formation and change. The status of frequency effects in such models is not well understood. We compare frequency effects in auto-associative memory models of attitudes to the well-established frequency effects found in the ACT-R cognitive architecture. We found striking differences between the model classes, but only under some conditions. We discuss future directions that might stem from this provisional work.

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Modeling the role of attachment in the development of reciprocity and generosity

We posit that early attachment to kith and kin has a marked influence on later life reasoning and especially on generosity toward others. We present a series of computational experiments showing that the final (adult) levels of generosity differ depending on such early life exposure, and this independently of the otherwise homogeneous reasoning behavior. The benchmark experiment defines a developmental progression of three stages, from attachment only to perception of cooperative or non-cooperative actions of others in a controlled social environment to finally complex environments of arbitrary participants. We use as a behavioral basis the well-known Iterated Prisoner's Dilemma game and its classic strategy Tit-For-Tat in a simulated society of individuals. We show that in the final stage of an arbitrary complex society the social scores obtained by the developing individuals are consistently higher than the reference, undeveloped (adult) individuals, and that this is due to the developed degree of nonzero generosity. We also show that individuals with a disturbed understanding of others' emotional behavior (thus of attachment) but with intact reasoning tend to be more reciprocal and less generous in the end. On the other hand, individuals with the opposite disturbance of the understanding of reasoning but with intact understanding of others' emotional behavior tend to be far more impulsive and behave as driven by attachment only. A succession of generations of typical, developing agents stabilizes the levels of generosity in the society. The effect of various parameters on the developed behaviors is also studied. Further implications of this developmental model are finally given.

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Session:
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Towards a Comprehensive Summary of the Senses for Cognitive Architectures

It is widely accepted that there are five senses. There, however, appear to be several more. This paper attempts to provide and describe a comprehensive list of sensors that might be found in a complete cognitive architecture. We also briefly note how widely used these senses have been and which ones could yet be implemented in an architecture.

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Session:
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From States to Transitions: Discrete Time Markov Chain in Affect Dynamics Psychometric Models

Affect dynamics, or the study of changing patterns of emotional responses across time, has emerged as a key field of research in Mathematical Psychology. Traditionally, Affect dynamics research has relied on the Experience Sampling Method (ESM), a data gathering technique in which participants describe their feelings, thoughts, and behaviors at various times throughout the day. This technique studies Intensive Longitudinal Data (ILD) using Mixed Linear or Nonlinear Models (MLM) or Vector Autoregressive Models (VARs) (VAR). These theories characterize emotion in terms of time and complexity. However, they fail to recognize the underlying unity of emotional dynamism: the transition between affects. Although emotions occur in a sequential sequence, the transition between them takes into account the previous state in comparison to the current one. Individuals can experience and describe many emotions at the same time, but one feeling often gains precedence, influencing or being compared to the previous one. In this paper, we will show how to use and implement discrete Markov chains to evaluate each transition between past and current emotional states, while neglecting earlier transitions in the same way that a Markov chain does. Researchers may use Markov chains to quantify the odds of migrating between distinct emotional states across time, allowing for a better understanding of affect dynamics. This method not only overcomes the constraints of traditional data gathering and processing approaches, but it also allows for a more sophisticated investigation of the processes driving emotional variations.

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Exploring the Utility of ACT-R models as Psychometric Tools: Estimated RL Learning-rate Predicts Learning Strategy.

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Session:
ICCM Posters

There is significant utility in determining individual memory characteristics, as these might affect learning strategy. This study aimed to assess how well estimated model parameters that reflect individual cognitive characteristics, predict learning strategy. A weighted mixture model based on ACT-R, of the stimulus-response learning task (RLWM, Collins, 2018) that contained declarative (LTM) and procedural memory (RL) components was used. Learning strategy was measured by estimating what percentage of trials were learned with LTM vs RL. The ACT-R LTM parameters speed of forgetting, (SoF, which measures memory decay rate, Pavlik & Anderson, 2008) and spreading activation (S, working memory capacity analog) and RL learning rate parameter (α) were estimated for each individual by selecting the best-fitting set of parameters to behavioral data. We hypothesize that the mostly-LTM group would have significantly higher S values and lower SoF values compared to the mostly-RL group. We expected that the mostly-RL group would have higher learning rate values. This would suggest that ultimate learning strategy choices might rely on available individual memory characteristics. Model fits were remarkably good, achieving low root-mean-squared-error (M:0.064, SEM=0.0012). To test our hypothesis, participants were grouped into 'mostly-LTM' (greater than 50% of trials were performed with the LTM model) and 'mostly-RL' (greater than 50% RL engagement). We found that the RL parameter learning rate was a significant predictor of learning strategy ($p < 0.0001$) but not the declarative SoF ($p=0.196$) and S parameters ($p=0.424$). Our results suggest that individual differences might be best captured by RL models, compared to models of declarative memory.

Identifying Transfer Learning in the Reshaping of Inductive Biases

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Transfer learning, the reuse of newly acquired knowledge under novel circumstances, is a critical hallmark of human intelligence, yet the underlying computations have been little investigated in humans. We argue that successful transfer learning upon task acquisition is ensured by updating inductive biases and transfer of knowledge hinges upon capturing the structure of the task in the inductive bias. To explore this, we trained participants on a non-trivial visual stimulus sequence task (Alternating Serial Response Times, ASRT). During the training, participants were trained in two distinct sequences successively, while the underlying structure of the task remained the same. We analyzed the acquired knowledge by recovering individual internal models of the task using infinite Hidden Markov Models. Our results show that beyond the acquisition of the stimulus sequence, our participants were also able to update their inductive biases. Acquisition of the new sequence was considerably sped up by earlier exposure, but this enhancement was specific to individuals showing signatures of abandoning initial inductive biases. Enhancement of learning was reflected in the development of a new internal model. Additionally, our findings highlight the ability of participants to construct an inventory of internal models and alternate between them based on environmental demands. Further investigation of the behavior during transfer revealed that it is the subjective internal model of individuals that can predict the transfer across tasks. Our results demonstrate that even imperfect learning in a challenging environment helps learning in a new context by reusing the subjective and partial knowledge about environmental regularities.

Developing and Evaluating a Computational Cognitive Model of Sensorimotor Grounded Action Selection Based on Eye-movement Behavior

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Sensorimotor grounding of cognitive processes may be the key to why humans exhibit efficient goal-directed behavior in a variety of dynamic environments. Modeling such behavior computationally poses a challenge as the model has to exhibit equally dynamic motor control in order to ground cognitive processes in it. Once the computational model has been developed, the next challenge lies ahead: how to evaluate the model behavior using human data? Here we present an eye tracking experiment to investigate action control in dynamic environments in which fixational eye movements reflect cognitive processes of action selection. Slightly increased uncertainty in motor control leads to more cautious action selection shown by fixations being initiated closer to a reference point, whereas strongly increased uncertainty leads to the need to monitor the environment for potential threats and thus greater distances to the reference point. We equip a computational model with the hypothesized action selection processes and single out the central parameter within its structure. In the last section, a likelihood method is discussed that could be used to evaluate the model based on human eye- movement behavior and to infer the parameter value.

Incorporating Cognitive Factors into Models of Speech Motor Control

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Sensorimotor learning is defined as one's ability to interact with the environment by interpreting the sensory world and responding to it with the motor system. Sensorimotor learning in speech has been shown to be influenced by cognition, but most models of speech mechanisms, including the DIVA model (Tourville & Guenther, 2011), do not include cognitive factors like attention or memory. Nonetheless, speech motor control is observably disrupted in individuals with impaired memory function (e.g., people with Alzheimer's disease, Liu et al., 2012), and even in typical speakers, there appears to be a relationship between speech motor learning and memory capacity (Lametti et al., 2012), that can vary quite widely. We explore the plausibility of incorporating existing cognitive modeling paradigms, like ACT-R, with models of speech production, to better define the role of memory in speech tasks. Specifically, we consider the hypothesis that incorrect responses in a pitch perception task result from a failure to retrieve the memory of the target pitch. The ranges of time scales and decay rates that result in retrieval failure can guide the implementation of a more complete model that integrates elements of both cognitive models and models of speech production.

Predicting learning and retention in a complex task

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This paper reports an experiment investigating learning and retention in a complex task over multiple sessions across an extended period of time. The primary aim of the experiment is to evaluate the Predictive Performance Equation (PPE: Jastrzembski & Gluck, 2009) a model of learning and forgetting that predicts retention based on past performance. The second aim is to test a taxonomy for knowledge, skills and attitudes and a competence retention analysis technique developed to improve competence retention in military training (Cahillane, Launchbury, MacLean, & Webb, 2013). Participants were trained over 16 weeks on the Multi-Attribute Task Battery (MATB: Comstock Jr & Arnegard, 1992), a computer-based task analogous to piloting an aircraft. The study reveals significant variation in learning profiles for the MATB sub-tasks and demonstrates the PPE's ability to make accurate predictions of human performance over intervals ranging from 27 to 111 days.

Inhibitory Control Deficits in Syndromes Associated with Frontotemporal Lobar Degeneration

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Disinhibition is a prominent feature of syndromes associated with frontotemporal lobar degeneration (FTLD), encompassing impulsive behaviours and difficulty suppressing inappropriate or habitual responses. Being disinhibited in these syndromes has been linked to higher caregiver burden, earlier institutionalisation, and poorer prognosis (Murley et al., 2021). There are currently no treatments for disinhibition in FTLD. However, an avenue for potential treatment is that of neurotransmitter deficits. Gamma-aminobutyric acid (GABA) and noradrenaline deficits in FTLD are well established and are correlated with disinhibition in isolation (Murley et al., 2020; Ye et al., 2023). To develop and validate treatment strategies for disinhibition, we need to understand the delicate balance of neurotransmitter deficits in these syndromes and their link to disinhibition.

Here we use a manual stop-signal task to quantify inhibitory control in Progessive Supranuclear Palsy (PSP, Richardson's syndrome, n= 5), behavioural variant frontotemporal dementia (bvFTD; n = 9) and age- and sex-matched healthy adults (n=14). The stop-signal task is a well-established tool to quantify inhibitory control, with trans-species and trans-diagnostic utility.

We confirm that patients with PSP and bvFTD are impaired on the stop signal task (SSRT; M = 301.38, SD = 98.87) compared to controls (M = 187.38, SD = 32.78, p = 0.0003). Ongoing work is analysing the contribution of GABA-ergic and noradrenergic deficits to these deficits in inhibitory control.

Understanding the variance of inhibitory control has implications for timing of symptom onset, prognostication, and the development of pharmacological interventions to mitigate the behavioural challenges faced by affected individuals and their caregivers.

Hey Pentti, We Did It!: A Fully Vector-Symbolic Lisp

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Kanerva (2014) suggested that it would be possible to construct a complete Lisp out of a vector-symbolic architecture. We present the general form of a vector-symbolic representation of the five Lisp elementary functions, lambda expressions, and other auxiliary functions, found in the Lisp 1.5 specification (McCarthy, 1960), which is near minimal and sufficient for Turing-completeness. Our specific implementation uses holographic reduced representations (Plate, 1995), with a lookup table cleanup memory. Lisp, as all Turing-complete languages, is a Cartesian closed category (nLab authors, 2024), unusual in its proximity to the mathematical abstraction. We discuss the mathematics, the purpose, and the significance of demonstrating vector-symbolic architectures' Cartesian-closedness, as well as the importance of explicitly including cleanup memories in the specification of the architecture.

What makes a model ”fit”? Comparing metrics of model quality in Dynamic Causal Modeling of fMRI data

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Model quality is generally determined by some metric of fit that represents how well the model captures the target behavior. However, as models become more complex, it becomes increasingly difficult to determine how well a given model is doing, and to compare it to alternates. In recent work comparing different accounts of high level cognitive structure in the brain using Dynamic Causal Modeling (DCM), the Common Model of Cognition (CMC) was determined to be the most plausible model configuration using Bayesian Model Selection (BMS). This paper explores some lower level comparison metrics in an effort to gain a better understanding of what contributes to a model's overall "fit" to complex data, with the goal of creating additional methods for evaluating model quality.

Integrating Cognitive Models of Human Perception and Computer Vision Systems

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Recent advances in self-supervised deep learning computer vision algorithms have resulted in significant improvement across several benchmark tasks including image classification and object detection. Similar to humans, these deep learning models are able to perform well on new tasks absent of task-specific guidance in the form of new labeled training data. The seemingly human-like ability that deep learning-based computer vision systems possess to learn robust representations that transfer between a variety of tasks raises two key questions:
1. How similar are learned representations from modern deep learning models and computational cognitive models of human visual perception?
2. Can we introduce a new objective during the training of a deep learning model to guide the model towards learning more human-like representations?
We address the first question by characterizing the relation between modern deep learning vision transformer models and models of human visual perception. To address the second question we introduce a novel training regime for deep learning models that encourages representational alignment to cognitive models of human perception. We compare different deep learning and cognitive models and show that our Human Aligned Vision Transformer (HuViT) training objective results in learned representations that are more similar to those produced by models of human perception over an equivalent unmodified deep learning computer vision model while maintaining a similar level of performance on computer vision benchmark tasks.

A simple diffusion-based framework for modelling time-varying changes in task performance and strategy

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As people engage in tasks over extended periods, their psychological states change (e.g., due to practice effects or boredom). Despite this, the most common methods for modelling cognitive processes, such as evidence accumulation models, only consider a single estimate of a process across the duration of an experiment, therefore failing to account for important time-varying factors such as learning. In this study, we describe a simple method for modelling time-varying changes to diffusion model parameters by assuming that rather than being constant across time, their estimates follow theoretically informed trial-varying or block-varying functions (e.g., exponential functions). Focusing on two parameters, drift-rate (task efficiency) and threshold (caution) and a number of candidate time-varying functions, we assessed 1) the measurement properties of this framework, 2) the extent to which these models could describe empirical data from three typical experimental psychology paradigms over and above the standard diffusion model, and 3) how much the standard diffusion model was mislead by time-varying processes in these data.

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