18–21 July, 2023
The University of Amsterdam

MathPsych | ICCM EMPG | 2023

56th Annual Meeting of the Society for Mathematical Psychology

21st International Conference on Cognitive Modeling

52nd Meeting of the European Mathematical Psychology Group

Contents

Welcome

Welcome to the joint meeting of the Society for Mathematical Psychology, the International Conference on Cognitive Modeling, and the European Mathematical Psychology Group. I am sure we are all thrilled to be able to meet in person and are excited for the new ideas and collaborations that will be generated from this meeting.

This year, we have even more opportunity than usual to meet our colleagues and expand our awareness of novel approaches in mathematical psychology and cognitive modeling: Thanks to the contributions of all three participating groups, we have the highest number of talk submissions and the highest projected attendance of any meeting in our history! Our program includes presentations representing the full range of topics in mathematical psychology and cognitive modeling, multiple opportunities to develop skills through workshops, and symposia on many of the most pressing topics in our fields, including one honoring a central figure in our society and Senior Fellow Award winner, the late A.A.J. (Tony) Marley. Additionally, we will have plenary talks from Professor Mateja Jamnik on building trustworthy AI, from Professor Birte Forstmann on using joint brain and behavior modeling to investigate decision processes in deep brain networks, and from Estes Early Career Award winner, Dr. Adam Osth, on examining the relationship between novel features and the distinction between separable and integral stimulus properties in episodic memory.

Looking forward to further opportunities to come together, I hope you will join us for the Math-Psych symposium at Psychonomics this November in San Francisco and another Virtual MathPsych/ICCM meeting next year in June. As we confirm details, we will continue to distribute information on our website, mathpsych.org, our mailing list (see `https://mathpsych.org/page/mailing-lists` to subscribe) and on social media (@socmathpsych). Details of the 2024 Annual Meeting will be announced at the business meeting this year.

Finally, thank you to the outstanding team behind the conference this year, led by Dora Matzke, Catherine Sibert, Marieke Van Vugt, and Michael Nunez with extensive and invaluable support from our Secretary/Treasurer, Leslie Blaha.

Enjoy the conference!

Regards,

Joe Houpt
President of the Society for Mathematical Psychology

mathpsych.org

About MathPsych / ICCM / EMPG 2023

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.

EMPG

The European Mathematical Psychology Group (EMPG) is an informal association of scientists in mathematical psychology. The group was founded in 1971 in Paris. It has not been formally organized as a society, although has been described as the "European branch" of the Society for Mathematical Psychology. It holds a meeting each year in a European city.

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.

Wi-Fi at the Conference Location

As a guest, you have the following options for using the wireless network at the University of Amsterdam (UvA).

1. Eduroam wireless network for guest users from other educational institutes. Log in using the account of your own institute.
2. UvA Open Wi-Fi network. This network does not require registration or passwords.

UvA wireless users must observe the ICT Code of Conduct
Users who do not obey the ICT Code of Conduct risk being refused access to the UvA-net. Using the UvA-net to distribute copyrighted materials is prohibited. If you are using BitTorrent to download material, switch off your BitTorrent programme before logging on to the UvAweb.

Lunch venues around campus

Around the campus you can find several options to enjoy a lovely lunch. Do like the students do: grab a quick lunch at the supermarket and sit down near the canal. Or get your lunch at a nearby café or a restaurant.

For your convenience, you can find an interactive list of places where to get food in the MathPsych / ICCM / EMPG 2023 Google map. Scan the following QR code to access the map:

Otherwise, below is a list of the recommended venues.

1. **Food Court at UvA** €5-10
   - Multiple cuisines including Vietnamese, Syrian/Lebanese kebab, Dutch broodjes (sandwiches) and pizza
   - Campus restaurant in building H
   - enjoytoday.amsterdam/food-uva
2. **Albert Heijn** €5-10
   - Supermarket, also offers lunch deals for fresh sandwiches, salads, sushi, etc. Unfortunately it is sometimes difficult to pay at this location without a Dutch bank card.
   - Sarphatistraat 141
   - ah.nl
3. **The Breakfast Club** €10-15
   - Sandwiches, pancakes, breakfast
   - Roetersstraat 10 A
   - thebreakfastclub.nl
4. **CREA Café** €5-10
   - Sandwiches, soup, snacks
   - Nieuwe Achtergracht 170
   - creacafe.nl
5. **Bagels & Beans** €5-10
   - Bagels, coffee
   - Roetersstraat 2 A

bagelsbeans.nl

6. **Bar Lampicka** €15-20
   - Sandwiches, burgers, and fries
   - Sarphatistraat 23
   - barlempicka.com
7. **Cantina Caliente** €10-15
   - Latin American cuisine
   - Roetersstraat 192
   - cantinacaliente.nl
8. **Hotel Arena** €15-20
   - Mediterranean cuisine
   - 's-Gravesandestraat 55
   - hotelarena.nl
9. **De Pizzabakkers** €10-15
   - Pizza
   - Plantage Kerklaan 2
   - depizzabakkers.nl
10. **Pizzeria "Palorma"** €15-20
    - Pizza
    - Plantage Kerklaan 28
    - restaurantguru.com/Palorma-Amsterdam
11. **Pizzeria Steakhouse La Roma** €10-15
    - Pizza
    - Plantage Kerklaan 32HS
    - restaurantguru.com/La-Roma-Amsterdam
12. **Cantarell Weesperplein B.V.** €5-10
    - Fast food
    - Weesperplein 13-15
    - cantarell.nl
13. **Café Noir** €5-10
    - Sandwiches, salads
    - Weesperplein 19-21
    - cafenoiramsterdam.nl
14. **Lebkov & Sons Roeterseiland** €5-10
    - Sandwiches and coffee bar
    - Roetersstraat 15
    - lebkov.nl
15. **Coffee & Bites** €10-15

Burgers and fries

Plantage Middenlaan 44-HS

coffeeandbites.amsterdam

16. **Box Sociaal** €15-20

Fusion, brunch

Plantage Middenlaan 30A

boxsociaal.com

17. **De Plantage** €5-10

French cuisine

Plantage Kerklaan 36

caferestaurantdeplantage.nl

18. **New Happy Corner** €10-15

Chinese cuisine

Plantage Middenlaan 30

restauranthappycorner.nl

19. **Café Koosje** €5-10

European cuisine

Plantage Middenlaan 37

koosjeamsterdam.nl

20. **Cafe Eik en Linde** €5-10

European cuisine

Plantage Middenlaan 22A

eikenlinde.nl

21. **Ponte Magro** €10-15

Italian cuisine

Nieuwe Kerkstraat 4

ponte-magro.nl

22. **Backhuys Amsterdam** €5-10

Sandwiches

Sarphatistraat 61

bakhuys-amsterdam.nl

23. **Café de Magere Brug** €10-15

European cuisine

Amstel 81

demagerebrug.nl

24. **Jen's Bing Cafe** €5-10

Taiwanese food and boba

Roetersstraat 4HS

jensbing.nl

25. **Sagra Food & Wine** €5-10

Italian to-go deli

Plantage Kerklaan 24HS

deplantage.amsterdam/en/single-company/sagra-food-wine-2

26. **Zirve** €5-15

Turkish fast food; Dürüm, kebab, kapsalon, etc.

Plantage Middenlaan 32

zirve.sitedish.shop

Room Designation

The five conference rooms are named after renowned Dutch methodologists, psychologists, and cognitive scientists. We would like to highlight their accomplishments here.

Adriaan Dingeman de Groot (1914-2006), Dutch psychologist, renowned for his contributions to cognitive psychology, conducted groundbreaking research on expertise and problem solving. He was professor at the University of Amsterdam, where he founded the Psychological Methods Unit. De Groot's work on chess experts' thought processes revolutionized our understanding of cognitive abilities and decision making.

Franciscus Cornelis Donders (1818-1889), a renowned Dutch psychologist and physician, made significant contributions to the field of cognitive psychology. He pioneered the measurement of cognitive functions, particularly response time, using his innovative "subtractive method." Donders' work laid the foundation for modern cognitive psychology and remains influential in the field today.

Géza Révész (1878-1955) was a Hungarian-Dutch psychologist known for his work in educational, differential psychology, and music cognition. He focused on understanding individual differences in intelligence and learning processes, emphasizing the importance of multiple dimensions of intelligence. His research contributed to personalized education and innovative teaching methods. Révész's work continues to influence the field of psychology and education. He also contributed to the field by co-founding the journal *Acta Psychologica* in 1935 together with David Katz.

Gideon Jan (Don) Mellenbergh (1938-2021) is a Dutch psychologist known for his significant contributions in the fields of psychometrics and quantitative psychology. Mellenbergh was professor at the University of Amsterdam and chair of the Psychological Methods Unit. His research in educational psychology, psychological assessment, and measurement theory, resulted in the development of advanced statistical models and refined measurement instruments. Mellenbergh's work has had an important impact on research design, data analysis, and the overall progress of psychological methods.

Margueritha (Rita) Vuyk, (1913-1989), the first female psychology professor in the Netherlands, has made significant contributions to psychology. She is known for her work on inductive reasoning in children. Her research at the University of Amsterdam focused on the interplay between thoughts, emotions, and behaviors, particularly in relation to childhood trauma and adult mental health. Vuyk's approach helped shift developmental psychology towards a more holistic approach to mental health in children.

Awards

Several awards will be announced during the SMP Business Meeting, 20 July 2023, 17:00-18:00, in C1.04 (de Groot)

William K. Estes Early Career Award: The Society for Mathematical Psychology presents an annual award for exceptional published research in the field of mathematical psychology by an early career investigator. Previously known as the "New Investigator Award," it was renamed after William K. Estes in 2009, recognizing his contributions to our Society and the field of mathematical psychology generally.

R. Duncan Luce Outstanding Paper Award: The Society for Mathematical Psychology presents an annual award for the most outstanding paper published in the *Journal of Mathematical Psychology* in the preceding three years. The award is named after R. Duncan Luce, recognizing his founding role in the field of mathematical psychology, and in our Society and the journal. The R. Duncan Luce Outstanding Paper Award is sponsored by Elsevier Inc.

***Computational Brain & Behavior* Outstanding Paper Award:** The Society for Mathematical Psychology presents an annual award for the most outstanding paper published in *Computational Brain & Behavior* in the preceding three years. The *Computational Brain & Behavior* Outstanding Paper Award is sponsored by Springer.

Society for Mathematical Psychology Senior Fellow Award: The Society for Mathematical Psychology presents an annual award honoring the lifetime contributions of a Society member. Winners are announced at the annual meeting of the Society, and participate in a "Conversation with the Senior Fellow" in the following annual meeting. Contributions can be in the any of the following areas: (1) Contributions in the mathematical modeling of psychological phenomena; (2) Mentorship of students, faculty, and others, with a particular focus on advancing the field of mathematical psychology; and (3) Service that has advanced the field of mathematical psychology.

Allen Newell Award for the Best Student-Led Paper: The International Conference on Cognitive Modeling will announce the 2023 Allen Newell Award for the Best Student-Led Paper, given annually to the most outstanding ICCM paper with a student as lead or sole author.

Best Poster Award: All attendees are invited to vote for the Best Poster Award during the Poster Session, 19 July, 17:00-20:00. The winner is announced at the SMP Business Meeting on 20 July.

WoMP Travel & Networking Award: Presenting one's research at professional meetings such as the Annual Meeting of the Society for Mathematical Psychology is an important way for individuals to become known in the professional community and to develop collaborative relationships with other professionals in the field. Given the relatively short time frame of the tenure period, it is essential that individuals begin to appear at professional meetings early in their careers. Therefore, the purpose of this award is to provide funds for graduate students and postdocs to participate in and network at the 2023 Professional Development Symposium and MathPsych / ICCM / EMPG 2023 Conference, University of Amsterdam, July 18-21, 2023.

The Women of Mathematical Psychology will announce the recipients of the 2023 WoMP Travel and Networking awards during the WoMP Professional Development Symposium on 18 July 2023, 14:00-17:30, in M1.03 (Vuyk), and they will be recognized again at the SMP Business Meeting.

Keynotes

Date	Session	
July 19	KN	ICCM Keynote: Prof. Mateja Jamnik in C1.04 (de Groot; Nieuwe Achtergracht 166)
July 20	KN	Early Career Award Lecture: Dr. Adam Osth in C1.04 (de Groot; Nieuwe Achtergracht 166)
July 21	KN	MathPsych Keynote: Prof. Birte Forstmann in C1.04 (de Groot; Nieuwe Achtergracht 166)

Workshops and social events

SE: Social event, WS: Workshop

Workshops (July 18 Morning)

Room	Session	
Mellenbergh | M1.01 09:00–12:30	WS	Workshop highlighting recent ACT-R work and trends
Donders | M1.02 09:00–12:30	WS	Principled Amortized Bayesian Inference with Deep Learning
Vuyk | M1.03 09:00–12:30	WS	Using reinforcement learning models in decision neuroscience: A tutorial with hierarchical Bayesian approaches with Stan
Révész | M0.02 09:00–12:30	WS	Hands-on tutorial on e-values, safe tests and anytime-valid confidence intervals for efficient statistical inference

Workshops (July 18 Afternoon)

Room	Session	
Mellenbergh | M1.01 14:00–17:30	WS	Workshop highlighting recent ACT-R work and trends
Donders | M1.02 14:00–17:30	WS	PsychoModels - A Database for Formal Models
Vuyk | M1.03 14:00–17:30	WS	Women of Mathematical Psychology Professional Development Symposium
Révész | M0.02 14:00–17:30	WS	Detecting single-trial cognitive events in EEG using hidden semi-Markov pattern analysis and the HMP python package

Social events

Date	Session	
July 18 12:30–14:00	SE	Woman of MathPsych Lunch in Overloop of Building M
July 18 17:30–20:00	SE	Opening Reception at CREA café
July 19 17:00–20:00	SE	Poster session in De Brug
July 20 18:30–19:30	SE	Canal cruise from Amstel to Banquet
July 20 19:30–22:00	SE	Banquet at IJKantine

MathPsych/ICCM/EMPG Talk Schedule | July 19

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

Révész M0.02		**09:00–11:00 | Symposium: Deterministic and Probabilistic Models of Choice**	
09:00–09:20	SY	**Cavagnaro, Daniel**	Identifying context effect sweet spots: There's an app for that!
09:20–09:40	SY	**Doignon, Jean-Paul**	Random ordering models and flow polytopes
09:40–10:00	SY	**Adaryukov, James**	If You Only Saw What I Saw: Modeling Heterogeneous Experiences and the Description-Experience Gap
10:00–10:20	SY	**Regenwetter, Mike**	(Ir)rationality of Moral Judgment
10:20–10:40	SY	**Suck, Reinhard**	Linear extensions of a partial order and NaP preferences
10:40–11:00	SY	**Marc, Jekel**	Improving Research Replicability with an Easy-to-Use App for Creating and Evaluating Deterministic and Probabilistic Models of Binary Choice

Mellenbergh M1.01		**09:00–11:00 | Symposium: Scientific Inference & Statistical Inference**	
09:00–09:20	SY	**Shiffrin, Richard M.**	The Chasm between Scientific and Statistical Inference Demonstrated by Lord's Paradox
09:20–09:35	SY	**Morey, Richard**	There is no such thing as "statistical inference"
09:35–09:50	SY	**Wagenmakers, Eric-Jan**	The Pros and Cons of Preregistration
09:50–10:05	SY	**Matzke, Dora**	Cure the cause, not the symptoms: Pre-registration will not remediate the perverse academic incentive system
10:05–10:20	SY	**van Ravenzwaaij, Don**	On the Utility of Hypothesis Testing and the Principle of Parsimony
10:20–11:00	SY		Plenary Session: Scientific and Statistical Inference Discussion

Donders M1.02	**09:00–10:40 | Eye Movements**

09:00–09:20	CT	**Ting, Chih-Chung**	Domain-specific overall value effects on choice behaviors and eye-movements
09:20–09:40	CT	**Visser, Ingmar**	A model-based approach to parsing eye-movement data
09:40–10:00	CT	**Rieskamp, Jorg**	Improving Decision Making Models by Considering Attention Processes: The Gaze-Weighted Advantage Race Diffusion Model
10:00–10:20	CT	**Turner, Brandon**	Consequences of mature cognitive control systems
10:00–10:40	CT	**Gluth, Sebastian**	A theory of information search in multi-attribute decisions

Vuyk M1.03	**09:00–11:00 | Similarity & Perception**		
09:00–09:20	CT	**Heathcote, Andrew**	Chronometric Psychophysics
09:20–09:40	CT	**Heller, Juergen**	A common representation of perceived intensity and the near-miss to cross-modal commutativity
09:40–10:00	CT	**Bennett, Murray**	A Bradley-Terry-Luce model-based analysis of human perception and computer vision in identifying melanoma lesions
10:20–10:40	CT	**Aho, Kaarina**	Systems alignment in concept learning: evidence from children's early concepts and beyond
10:40–11:00	CT	**Gillespie, Nathan**	Relating perception and memory for a novel set of reconfigurable auditory stimuli: a noisy exemplar approach

de Groot C1.04	**09:00–11:00 | Symposium: Deep Learning for Cognitive Modeling**		
09:00–09:20	SY	**Ghaderi-Kangavari, Amin**	Integrative neurocognitive approaches to understanding cognition through simultaneous analysis of EEG and behavioral data on single trials
09:20–09:40	SY	**Elsemüller, Lasse**	Comparing Bayesian hierarchical models: A deep learning method with cognitive applications

09:40–10:00	SY	**Liss, Julia**	Time to jump: Exploring the distribution of noise in evidence accumulation as a function of time pressure
10:00–10:20	SY	**Schumacher, Lukas**	Neural superstatistics for bayesian estimation of dynamic cognitive models
10:20–10:40	SY	**Schnuerch, Martin**	Fading memory, waning attention: Modeling output interference with a dynamic diffusion model
10:40–11:00	SY	**Radev, Stefan**	Compressing Bayesian Inference with Information Maximization

Révész M0.02	**11:20–12:40 | Quantum & Context Effects**		
11:20–11:40	CT	**Borghetti, Lorraine**	Evaluating the Generalizability of Diverse Models of Interference Effects
11:40–12:00	CT	**Dzhafarov, Ehtibar N.**	Contextuality and hidden variable models
12:00–12:20	CT	**Cai, Xiaohong**	Where are the context effects?
12:20–12:40	CT	**Trueblood, Jennifer**	Contextual Sensitivity in Naturalistic Multi-alternative Choice

Mellenbergh M1.01	**11:20–12:40 | Reinforcement Learning**		
11:20–11:40	CT	**Miletić, Steven**	Performance of the volatile Kalman filter in the reversal learning paradigm
11:40–12:00	CT	**Lee, Sang Ho**	Measuring impulsivity using a real-time driving task and inverse reinforcement learning
12:00–12:20	CT	**Bavard, Sophie**	It's not all about choices: the influence of response times on inferring other people's social preferences
12:20–12:40	CT	**Speekenbrink, Maarten**	"One step beyond...": Computational principles in social interaction

Donders M1.02	**11:20–12:40 | Cognitive Control**		
11:20–11:40	CT	**Jahansa, Paria**	Modeling response inhibition in the stop signal task: the copula approach

11:40–12:00	CT	**Weigard, Alexander**	Cognitive process modeling of context independence violations in the ABCD Study stop-signal task
12:00–12:20	CT	**Bompas, Aline**	Stop-Signal Reaction Time Largely Reflects Sensory and Motor Delays
12:20–12:40	CT	**Smith, Parker**	The neutral condition in conflict tasks: the implications of neutral condition RT behavior on modeling

Vuyk M1.03	**11:20–12:40 | Statistics: Order Constraints**		
11:20–11:40	CT	**Line, Emily**	Order constrained modeling and inference in psychology and law
11:40–12:00	CT	**Lin, Tzu-Yao**	Incorporating the Luce-Krantz threshold model into the cultural consensus theory for ordinal categorical data: A simulation study
12:00–12:20	CT	**García-Lapresta, José Luis**	Scoring functions in the setting of ordered qualitative scales
12:20–12:40	CT	**Chen, Meichai**	Order-constrained Inference: A Nuanced Approach to Hypothesis Testing

de Groot C1.04	**11:20–12:40 | Symposium: Complex Systems Analysis in Mental Health Research**		
11:20–11:40	SY	**Evers, Kyra**	Anticipating or merely characterizing change: How well do early warning signals work in more complex and chaotic regimes?
11:40–12:00	SY	**Waldorp, Lourens**	Early Warning Signals in psychopathology
12:00–12:20	SY	**Haslbeck, Jonas**	Improving Treatments for Panic Disorder using Computational Modeling
12:20–12:40	SY	**Hasselman, Fred**	The geometry of synchronisation: Quantifying the coupling direction of physiological signals within and between individuals using inter-system recurrence networks.

Mellenbergh M1.01	**15:20–17:00 | Risky Choice**

15:20–15:40	CT	**Olschewski, Sebastian**	Optimal Allocation of Time in Risky Choices under Opportunity Costs
15:40–16:00	CT	**Lasagna, Carly**	Mathematical modeling of risk-taking in bipolar disorder: Evidence of reduced behavioral consistency, with altered loss aversion specific to those with history of substance use disorder
16:00–16:20	CT	**Pachur, Thorsten**	The multiple attentional roots of probability weighting in risky choice
16:20–16:40	CT	**Lob, Aaron**	Modelling the influence of situational uncertainty on risk taking in everyday life
16:40–17:00	CT	**Danwitz, Ludwig**	Observational learning of Exploration Exploitation Strategies in Bandit Tasks

Donders M1.02	**15:20–17:00 | Bayesian Analysis**		
15:20–15:40	CT	**Behrens, Thea**	Connecting process models to response times through Bayesian hierarchical regression analysis
15:40–16:00	CT	**Lages, Martin**	A Hierarchical Signal Detection Model with Unequal Variance for Binary Responses
16:00–16:20	CT	**Snijder, Jean-Paul**	An Examination of Hierarchical Bayesian Dynamic Structural Equation Models in Stan
16:20–16:40	CT	**Brandtzæg, Ørjan Røkkum**	Nothing and the seven priors. Re-analysis of data on Bayesian priors.
16:40–17:00	CT	**Stevenson, Niek**	Bayesian hierarchical modelling for between-subject analysis

Vuyk M1.03	**15:20–17:00 | ICCM: Logic & Learning**		
15:20–16:00	CT	**Lommerzheim, Marcel**	Cognitive modeling of category learning and reversal learning
15:40–16:00	CT	**Sense, Florian**	Comparing Model Variants Across Experimental and Naturalistic Data Sets
16:00–16:20	CT	**Droop, Stephanie**	Extending counterfactual reasoning models to capture unconstrained social explanations

16:20–16:40	CT	**Sense, Florian**	Modeling Change Points and Performance Variability in Large-Scale Naturalistic Data
16:40–17:00	CT	**Brand, Daniel**	Uncovering iconic patterns of syllogistic reasoning: A clustering analysis

de Groot C1.04	**15:20–17:00 | Evidence-Accumulation Models: Caution and Prior Probability**		
15:20–15:40	CT	**Cerracchio, Ettore**	A diffusion model analysis of prior probability and spatial attention
15:40–16:00	CT	**Kucharsky, Simon**	Hidden Markov Models of Evidence Accumulation in Speeded Decision Tasks
16:00–16:20	CT	**Voss, Andreas**	Explaining Fast Errors in Perceptual Decision Making: Starting Point Variability or Jumping to Conclusion?
16:20–16:40	CT	**Lerche, Veronika**	The influence of catch trials on response caution – a diffusion model analysis
16:40–17:00	CT	**Baker, Sophie-Anne Helen**	The speed-accuracy tradeoff for embodied decision making

Révész M0.02	09:00–10:20 | Symposium: Computational Models in Affective Science		
09:00–09:20	SY	**Vanhasbroeck, Niels**	The Affective Ising Model: A nonlinear model of affect dynamics
09:20–09:40	SY	**Voodla, Alan**	AffectDDM – a computational perspective to affect generation in perceptual decisions
09:40–10:00	SY	**Yu, Kenny**	Multiple pathways to widespread fears: Disentangling idiosyncratic fear generalization mechanisms using computational modeling
10:00–10:20	SY	**Zhang, Lei**	Multiple facets of social influence in goal-directed learning

Mellenbergh M1.01	09:00–10:40 | Symposium: Bayesian Advances in Modeling Individual Differences		
09:00–09:20	SY	**Aust, Frederik**	Informative and efficient Bayesian hypothesis tests for lesion studies
09:20–09:40	SY	**Sarafoglou, Alexandra**	A framework to study individual differences in meaning representations
10:20–10:40	SY	**Mehrvarz, Mahbod**	Bayesian hierarchical model approaches for disattenuating correlation in studies of individual differences
09:40–10:00	SY	**Donzallaz, Michelle**	Comparing and exploring modeling solutions to the reliability paradox in conflict tasks
10:00–10:20	SY	**Hoogeveen, Suzanne**	Bayesian modeling approaches for individual differences in social cognition

Donders M1.02	09:00–10:40 | Symposium: Mental Architecture Model Identifiability Approaches		
09:00–09:20	SY	**Fific, Mario**	Modular Serial-Parallel Network (MSPN): A Unified Model for Hierarchical Cognitive and Perceptual Processes

09:20–09:40	SY	**Yang, Cheng-Ta**	Effects of Automation Accuracy and Task Difficulty on Decision-Making Efficiency: Insights from Systems Factorial Technology
09:40–10:00	SY	**Townsend, James T.**	The Change of speed of retrieval of items from long-term memory: Control by the parallel hazard functions in a parallel system
10:00–10:20	SY	**Houpt, Joe**	Selective influence and coactivity in accumulator models examined through the Grice representation
10:20–10:40	SY	**Chen, Ying-Yu**	Investigating the integration of two sources of visual information

Vuyk M1.03	**09:00–10:40 | Assessment**		
09:00–09:20	CT	**Adaryukov, James**	Worth the Weight: Integration of Verbal and Numeric Information in Graduate Admissions
09:40–10:00	CT	**Epifania, Ottavia**	matriKS: An R package for rule-based automatic generation of Raven-like matrices
10:00–10:20	CT	**Taatgen, Niels**	Identifying cognitive skills in student data with an application in education
10:20–10:40	CT	**Noel, Yvonnick**	A Beta Asymmetric Unfolding Model for Continuous Bounded Responses

de Groot C1.04	**09:00–10:40 | ICCM: Neuroscience I**		
09:00–09:20	CT	**Verwijmeren, Stephan**	A neural network simulation of event-related potentials in response to syntactic violations in second-language learning
09:20–09:40	CT	**Simone, Kathryn**	Improving Reinforcement Learning with Biologically Motivated Continuous State Representations
09:40–10:00	CT	**Stewart, Terry**	Novelty Detection, Insect Olfaction, Mismatch Negativity, and the Representation of Probability in the Brain
10:00–10:20	CT	**Adolfi, Federico**	Resource demands of an implementationist approach to cognition

10:20–10:40	CT	**Furlong, Michael**	Single neuron distribution modelling for anomaly detection and evidence integration

Révész M0.02	**11:00–12:00 | ICCM: Attention & Cognition**		
11:00–11:20	CT	**Conway-Smith, Brendan**	Metacognitive threshold: A computational account
11:20–11:40	CT	**Seitz, Florian**	Relative attention across features predicts that common features increase geometric similarity
11:40–12:00	CT	**Nicenboim, Bruno**	The CoFI Reader: A Continuous Flow of Information approach to modeling reading

Mellenbergh M1.01	**11:00–12:40 | Evidence-Accumulation Models: Methods**		
11:00–11:20	CT	**Chávez De la Peña, Adriana Felisa**	A Bayesian hierarchical implementation of the circular drift diffusion model
11:20–11:40	CT	**Hartmann, Raphael**	Partial derivatives and an adaptive rejection sampler for the Wiener diffusion model
11:40–12:00	CT	**Kuhne, Caroline**	Hierarchical Bayesian Estimation for Cognitive Models using Particle Metropolis within Gibbs (PMwG): A tutorial
12:00–12:20	CT	**Wang, Jiashun**	Exploring the neurally plausible assumptions of the Ising Decision Making model
12:20–12:40	CT	**Holmes, Bill**	PyBEAM: A Bayesian approach to parameter inference for a wide class of binary evidence accumulation models.

Donders M1.02	**11:00–12:40 | Probability & Randomness Judgement**		
11:00–11:20	CT	**Castillo, Lucas**	Modelling speeded random generation as sampling for inference
11:20–11:40	CT	**Spicer, Jake**	How do people predict a random walk? Lessons for models of human cognition
11:40–12:00	CT	**Sanborn, Adam**	Investigating the symmetry of human probability judgment biases

12:00–12:20	CT	**Fischer, Olivia**	Measuring polarization of risk perceptions
12:20–12:40	CT	**Fang, Jun**	Get'cha Head in the Game: Testing Context Effects for Naturalistic Stimuli in Basketball

Vuyk M1.03	**11:00–12:20 | Social Cognition**		
11:00–11:20	CT	**Tucker, Gabe**	A runnable neural network model of the structure and dynamics of human personality embedded in a virtual environment
11:20–11:40	CT	**Wakai, Taisei**	Cognitive Modeling of Attitude Change Process Through Persuasion
11:40–12:00	CT	**Montgomery, Lauren**	The wisdom of the crowd when people choose what they rank
12:00–12:20	CT	**van der Maas, Han**	Cascading transitions in psych-social systems

de Groot C1.04	**11:00–12:40 | Symposium: The Emerging Field of Bayesian Graphical Modeling in Psychology**		
11:00–11:20	SY	**Marsman, Maarten**	Bayesian graphical modeling in network psychometrics
11:20–11:40	SY	**Haslbeck, Jonas**	Evaluation of Network Models for Ordinal Data
11:40–12:00	SY	**Keetelaar, Sara**	An overview of parameter estimation methods in the Ising model
12:00–12:20	SY	**van den Berg, Don**	Hierarchical Gaussian graphical models and group level networks
12:20–12:40	SY	**Huth, Karoline**	Three approaches for conditional independence testing: An introduction and application within psychopathology research

Mellenbergh M1.01	**15:20–17:00 | Thinking & Reasoning**		
15:20–15:40	CT	**Lee, Michael**	Optimal and human performance buying airline tickets

15:40–16:00	CT	**Hancock, Thomas**	An integrated choice and latent variable decision field theory model linking preferential choice responses and thinking patterns.
16:00–16:20	CT	**Katsikopoulos, Konstantinos**	A Simple Model for Mixing Intuition and Analysis
16:20–16:40	CT	**Maksimenko, Vladimir**	Informing ethical decisions of autonomous vehicles through video-based choice experiments and brain recordings.
16:40–17:00	CT	**Cruz, Nicole**	What do people mean by "If there is not beer then there is wine"?

Donders M1.02	**15:20–16:20** | **ICCM: Cognitive Architectures**		
15:20–15:40	CT	**Mekik, Can (John)**	An integrative model of human response processes in Raven's Matrices
15:40–16:00	CT	**Akrum, Ivana**	From knowledge graph to cognitive model: a method for identifying task skills
16:00–16:20	CT	**Curley, Taylor**	Using neural networks to create fast and reusable approximate likelihood functions for ACT-R

Vuyk M1.03	**15:20–17:00** | **Bias, Beliefs, & Errors**		
15:20–15:40	CT	**Tehranchi, Farnaz**	Cognitive Models for Human Error Generation and Detection
15:40–16:00	CT	**Epping, Gunnar**	Improving machine learning model calibration using probabilistic labels obtained via wisdom of the crowd
16:00–16:20	CT	**Banisch, Sven**	Measuring processing biases in balanced argument experiments
16:20–16:40	CT	**Tan, Nicole**	The Causal Effect of Anxiety on Jumping-to-Conclusion Bias
16:40–17:00	CT	**Groß, Julia**	Towards Theory Integration: Connecting Hindsight Bias and Seeding Effects

de Groot C1.04	**15:20–17:00** | **Knowledge Spaces**

15:20–15:40	CT	**Anselmi, Pasquale**	Procedures for constructing minimal, yet maximally informative tests for skill assessment
15:40–16:00	CT	**Noventa, Stefano**	Toward a unified perspective on assessment models, a perspective on KST, CDA, and IRT
16:00–16:20	CT	**Brancaccio, Andrea**	Modeling symmetries in human problem solving and problem space homomorphisms
16:20–16:40	CT	**Spoto, Andrea**	On the identifiability of the Polytomous Local Independence Model (PoLIM)
16:40–17:00	CT	**Stefanutti, Luca**	The dimension of a knowledge space

Révész M0.02	09:00–10:20 | Dyad and Agent Modelling		
09:00–09:20	CT	**Herchenhahn, Lena**	Narcissism and the social context: An agent-based modeling approach
09:20–09:40	CT	**Yasar, Alperen**	Mental model evolution in social networks
09:40–10:00	CT	**Westermann, Stefan**	A formal model of affiliative interpersonality

Mellenbergh M1.01	09:00–10:40 | ICCM: ACT-R		
09:00–09:20	CT	**Blaha, Leslie**	A Cognitive Model of a Temporal Binding Task
09:20–09:40	CT	**Nagashima, Kazuma**	ACT-R Modeling of Rapid Motor Learning Based on Schema Construction
09:40–10:00	CT	**Hough, Alexander**	An initial cognitive model of a radar detection task
10:00–10:20	CT	**Roessling, Grace**	Improving Visuomotor Control of a Cognitive Architecture
10:20–10:40	CT	**Wu, Siyu**	Long Road Ahead: Lessons Learned from the (soon to be) Longest Running Cognitive Model

Donders M1.02	09:00–10:40 | Evidence-Accumulation Models: Applications I		
09:00–09:20	CT	**Singmann, Henrik**	Neither measurement error nor speed-accuracy trade-offs explain the difficulty of establishing attentional control as a psychometric construct: Evidence from a latent-variable analysis using diffusion modeling
09:20–09:40	CT	**Hasan, Eeshan**	The Role of Salience-Driven Attention on Multialternative Multiattribute Choice
09:40–10:00	CT	**Baker, Sophie-Anne Helen**	Degenerate boundaries for multiple-alternative decisions

10:00–10:20	CT	**Brede, Max**	Frustration of the achievement motive: Insights from a diffusion model analysis
10:20–10:40	CT	**Ratcliff, Roger**	A Spatially Continuous Diffusion Model of Visual Working Memory

Vuyk M1.03	**09:00–10:40 | Neuroscience II**		
09:20–09:40	CT	**Geuzebroek, Anna**	The impact of warning cues on detection decisions in continuous monitoring situations
09:40–10:00	CT	**Ging-Jehli, Nadja**	Dissecting time-varying decision dynamics in the basal ganglia: how the weighing of distinct sensory information contributes to task difficulty and perceptual conflict
10:00–10:20	CT	**Balakrishnan, Jerry**	Bayesian Decoding As A Testing and Development Link Between Behavioral and Neurological Models
10:20–10:40	CT	**Kahana, Mike**	The Penn Electrophysiology of Encoding and Retrieval Study

de Groot C1.04	**09:00–12:40 | Symposium In Honor of AAJ Marley**		
09:00–09:20	SY		Plenary Session: Tributes to AAJ Marley
09:20–09:40	SY	**Doignon, Jean-Paul**	On the best-worst choice model of Marley and Louviere
09:40–10:00	SY	**Amani Rad, Jamal**	The role of reinforcement learning in shaping the decision policy in methamphetamine use disorders
10:00–10:20	SY	**Kilani, Karim**	Best, worst, and best & worst choice probabilities for logit and reverse logit models
10:20–10:40	SY	**Hancock, Thomas**	An integrated choice and response time decision field theory model: new insights on choice response times in multi-attribute, multi-alternative choice.
11:00–11:20	SY	**Sokratous, Konstantina**	Machine Learning approaches to estimating and comparing models of intertemporal choice

11:20–11:40	SY	**Collewet, Marion**	Preference estimation from point allocation experiments
11:40–12:00	SY	**Gronau, Quentin**	Do Discrete Choice Experiments and Rating Scales Elicit the Same Preference Judgments?
12:00–12:20	SY	**Li, Xinwei**	The role of decoy effects in nudging preferences for electric vehicles: A novel approach to fuse preference data with and without eye-tracking
12:20–12:40	SY	**Diederich, Adele**	Cube model: Predictions and account for best-worst choice situations with three choice alternatives

Révész M0.02	**11:00–12:20 | Statistics & Individual Differences**		
11:00–11:20	CT	**Ly, Alexander**	Safe anytime live and leading interim meta-analysis
11:20–11:40	CT	**Bartoš, Frantisek**	Robust Bayesian Meta-Regression: Publication bias adjusted moderator analysis
11:40–12:00	CT	**Perquin, Marlou**	Temporal structure in sensorimotor variability is a reliable trait, but is unrelated to attentional state measures
12:00–12:20	CT	**Dome, Lenard**	g-distance: A new framework for comparison of model and human heterogeneity

Mellenbergh M1.01	**11:00–12:40 | Symposium: Investigating Within-Trial Timing of Cognitive Processes with EEG**		
11:00–11:20	SY	**Van Maanen, Leendert**	Detecting multiple sequential decisions within a single trial using EEG
11:20–11:40	SY	**Nunez, Michael D.**	When does evidence accumulation begin after a visual stimulus? Evidence from neurocognitive modeling of EEG and behavior
11:40–12:00	SY	**Krause, Joshua**	Untangling frequency and word type effects on lexical decision processes
12:00–12:20	SY	**Schubert, Anna-Lena**	Linking stages of conflict-processing across behavioral and electrophysiological data

12:20–12:40	SY	**Verguts, Tom**	Modulations of theta frequency for cognitive control in behavior and in EEG

Donders M1.02	**11:00–12:40 | Confidence**		
11:00–11:20	CT	**Bontje, Floor**	Are you sure? Modelling Local Confidence of a Driver
11:20–11:40	CT	**Hellmann, Sebastian**	Magnitude-sensitive sequential sampling models of confidence
11:40–12:00	CT	**Msheik, Ramla**	Evidence accumulation explains the duration of perceptual experience and its associated confidence
12:00–12:20	CT	**West, Rebecca**	Computational models of decision confidence for uni- and multi-dimensional perceptual decisions
12:20–12:40	CT	**Rausch, Manuel**	Measures of metacognitive efficiency across cognitive models of decision confidence

Vuyk M1.03	**11:00–12:20 | ICCM: Decision Making**		
11:00–11:20	CT	**Tehranchi, Farnaz**	A pipeline for analyzing decision-making processes in a binary choice task
11:20–11:40	CT	**Heinrich, Nils**	A Straightforward Implementation of Sensorimotor Abstraction in a Two-Layer Architecture for Dynamic Decision-Making
11:40–12:00	CT	**Borghetti, Lorraine**	Comparing Classical and Quantum Probability Accounts of the Interference Effect in Decision Making
12:00–12:20	CT	**Bensilum, Mark**	Quantifying performance in magnitude comparison tasks using a drift-diffusion model

Mellenbergh M1.01	**15:20–17:00 | Categorization**		
15:20–15:40	CT	**Zhang, Qiong**	Towards a Generalized Bayesian Model of Category Effects

15:40–16:00	CT	**Seitz, Florian**	Time pressure affects response precision but not psychological similarity in inferences from multiple features
16:00–16:20	CT	**Villarreal, J. Manuel**	Coupled Hidden Markov models for Categorization
16:20–16:40	CT	**Schlegelmilch, René**	Towards unifying category learning, probability learning and risky gambling using the CAL framework of rule and attention learning
16:40–17:00	CT	**Seitz, Florian**	Human category inference is mostly independent of the distribution of features within categories

Donders M1.02	**15:20–17:00 | Evidence-Accumulation Models: Applications II**		
15:20–15:40	CT	**Stuchlý, Erik**	To simulate or not: the mechanistic underpinnings of predicting the decisions of other people
15:40–16:00	CT	**March, Jennifer**	Do not make decisions on an empty stomach: the impact of hunger state on attention and dietary choice processes
16:00–16:20	CT	**Buckell, John**	A discrete mixture decision field theory model for capturing preference and decision process heterogeneity in health choices.
16:20–16:40	CT	**Oberbauer, Barbara**	Understanding the dynamics of serial dietary decisions through the lens of sequential sampling modeling
16:40–17:00	CT	**Van Vugt, Marieke**	Drift diffusion model-informed EEG and dynamical systems to uncover the mechanisms of depressive thinking and decision making

Vuyk M1.03	**15:20–17:00 | Statistical Methods**		
15:20–15:40	CT	**Ariens, Sigert**	One does not simply correct for serial dependence
15:40–16:00	CT	**Steinhilber, Meike**	Sequential ANOVA: An Efficient Alternative to Fixed Sample Designs
16:00–16:20	CT	**Li, Yiqi**	Assessing goodness-of-fit of the queueing model of visual search to accuracy data

16:20–16:40	CT	**Nett, Tillmann**	Towards a formal approach for (negative) Delta-Plots
16:40–17:00	CT	**Ludwig, Casimir**	Navigating cognitive parameter space

de Groot C1.04	**15:20–17:00** | **Memory**		
15:20–15:40	CT	**Dunn, John**	Measurement of memory
15:40–16:00	CT	**Meyer-Grant, Constantin**	ROC Asymmetry and the Target-Probe Invariance Assumption in Recognition Memory
16:00–16:20	CT	**Cornell, Charlotte**	Improving Memory Search through Model-Based Cue Selection
16:20–16:40	CT	**Pala, Deniz**	Retrieving dynamically and effectively from memory (D-REM): A recognition memory model with dynamic decision making mechanism
16:40–17:00	CT	**Sommer, Joseph**	Order-Constrained Models of Memory

Administrative meetings

IO: Invitation only, MO: Members only

Board meetings

Board meetings are by invitation only.

Date	Board meetings	
July 19 12:40–14:00	IO	JMP Board Meeting in C1.06
July 20 12:40–14:00	IO	SMP Board Meeting in C1.06
July 21 12:40–14:00	IO	CBB board meeting in C1.06

Business meetings

All conference attendees are invited to attend the Society business meetings. All members are strongly encouraged to attend.

Date	Business meetings	
July 19 12:40–14:00	MO	ICCM Business Meeting in M1.02
July 20 17:00	MO	SMP Business Meeting in C1.04 (de Groot)

Workshop abstracts

Workshop highlighting recent ACT-R work and trends

Lebiere, Christian
Department of Psychology, Carnegie Mellon University, Pittsburgh, PA 15213 USA

Session:
Workshop Highlighting Recent ACT-R Work and Trends

The 30th Annual ACT-R Workshop will take place on Tuesday July 18, 2023 as part of the
MathPsych/ICCM conference. Virtual attendance is available at this zoom link: `https://cmu.zoom.us/j/95023169045?pwd=bWNwUFJuNmJDMjU2VnZhR3M3Yk9tdz09`
Recordings of the workshop will be made available.
Times listed are Amsterdam local time
Contact cl@cmu.edu with comments and inquiries.

Principled Amortized Bayesian Inference with Deep Learning

Radev, Stefan
Heidelberg University

Session:
Workshop: Principled Amortized Bayesian Inference with Deep Learning

This workshop will provide an introduction to deep learning methods and architectures for efficient Bayesian inference with complex models. It will include a self-contained theoretical part and a practical part, focusing on the topics of posterior estimation, model comparison, likelihood estimation, and model misspecification. In the theoretical part, participants will learn about neural density estimation with normalizing flows, simulation-based optimization, embedding networks, sequential and amortized inference, as well as the rationale of principled Bayesian workflows. In the practical part, participants will apply existing software packages for neural Bayesian inference (e.g., BayesFlow, SBI) to build their own amortized Bayesian workflows. Participants are highly encouraged to "bring" their own models and ideas to the workshop.

Using reinforcement learning models in decision neuroscience: A tutorial with hierarchical Bayesian approaches with Stan

Zhang, Lei
University of Birmingham

Session:
Workshop: Reinforcement learning models in decision neuroscience

Recent years have witnessed a dramatic increase in the use of reinforcement learning (RL) models in decision neuroscience and affective neuroscience. This approach, in combination with neuroimaging techniques such as functional magnetic resonance imaging, enables quantitative investigations into latent mechanistic processes underlying social decision-making. Additionally, there is a growing popularity of hierarchical Bayesian approaches for performing model estimation, which provides the granularity of population-level regulation meanwhile retains individual differences. However, cognitive and social neuroscientists do not necessarily have formal training in computational modeling, which involves multiple steps that require programming as well as quantitative skills. To bridge this gap, this tutorial will first present a comprehensive framework for the examination of (social) decision-making with the simple Rescorla-Wagner RL model. I will then provide a principled interpretation of the functional role of the learning rate parameter. I will also discuss potential misconceptions of RL models and provide an applicable workflow for applying RL models. Finally, I will showcase a few studies that applied RL modeling frameworks in decision neuroscience, including an emerging field of Computational Psychiatry. In the practical session, I will focus on a newly developed probabilistic programming language Stan (mc-stan.org), and an associated R package hBayesDM (github.com/CCS-Lab/hBayesDM) to perform hierarchical Bayesian analyses of a simple RL task. In sum, this tutorial aims to provide simple and scalable explanations and practical guidelines for employing RL models in order to assist both beginners and advanced users in better implementing and interpreting their model-based analyses.

Hands-on tutorial on e-values, safe tests and anytime-valid confidence intervals for efficient statistical inference

Recently developed safe tests based on e-values, and anytime-valid confidence intervals form a suite of statistical methods that simplify and optimise the design, conduct, and inferential process for both single-lab experiments and large-scale multi-lab (replication) studies.
Safe tests combine the interpretability of Bayes factors (i.e. measuring evidence for and against a null hypothesis) with frequentist power and type I error guarantees. These guarantees are maintained even if the safe test is conducted after each observation and used to determine whether the experiment should be (prematurely) stopped or continued. Similarly, unlike 95% (Bayesian) credible intervals and 95% (frequentist) confidence intervals, a 95% anytime-valid confidence interval will, with at least 95% chance, cover the true effect size regardless of whether or how data collection is stopped. In this workshop we will provide an introduction to this novel framework of statistical inference, and show how it can be exploited to yield more generalisable conclusions with less data. We will alternate between short theoretical lectures and hands-on practical sessions that focus on designing and making inference for practical problems with R/RStudio.

Grünwald, Peter
CWI Amsterdam/Leiden University

de Heide, Rianne
VU Amsterdam

Boehm, Udo
CWI

Turner, Rosanne J
CWI Amsterdam/University Medical Center Utrecht

Ly, Alexander
CWI Amsterdam

Session:
Workshop: Hands-on tutorial on e-values, safe tests and anytime-valid confidence intervals for efficient statistical inference

PsychoModels - A Database for Formal Models

van Dongen, Noah
University of Amsterdam, The Netherlands

Volz, Leonhard
University of Amsterdam

Session:
Workshop: PsychoModels - A Database for Formal Models

In this workshop, we will engage with participants in an effort to curate formal models in psychology. For this purpose, we introduce the PsychoModels database that is currently under development as a platform for researchers to find, use, or contribute data generative models. Included models are annotated with information such as the psychological context, the modelling framework used, data used to parameterize the model (if applicable), and descriptive overview of the objects and functions inside the model.
This workshop aims to test and improve a prototype in a crowdsourced manner, in order to improve the database and create a community around it. Similar efforts have led to thriving platforms in modelling communities in other scientific fields (such as BioModels for systems biology or CoMSES for computational social science) — and we believe that a comprehensive and well-indexed platform for computational models will be a valuable resource for psychology at large, and mathematical psychology in particular.
Firstly, a curated collection ensures that included models are clearly annotated and presented in a similar way, making it easier to skim a model and grasp its content than current repositories allow for. Secondly, this similar presentation facilitates a common language around modelling that makes it easier to communicate with other researchers. Thirdly, indexing model content allows to introduce search options across the model database and facilitate model review efforts, and the reuse or improvements of models in the database. Lastly, easing access to existing models and surrounding the database with educational materials will allow researchers with less experience in formalising their research to learn from best-practice.
During the workshop, participants will first be made familiar with the current functionality of the database by creating entries of their own computational models. Building on this, we aim to discuss improvements to the platform and solutions to potential problems. Finally, we will develop ideas for the subsequent promotion and structural integration into the psychological community.
We envision PsychoModels as a comprehensive resource that is exhaustive in its content and intuitive and beneficial a pleasure to use. This workshop aims to a) introduce modellers to the platform in its current state and benefits of such a resource and b) develop it with a community focus in mind, to design the usability according to researchers' needs.
In the end, participants will have contributed to a shared resource that can be used to advance research and education in mathematical psychology and beyond. Their contributions will be acknowledged on the website of the database and we will invite them for future collaboration.

Talk on responsible supervision (Dr. Tamarinde Haven)

When conducted in a manner that emphasizes rigorous and transparent research, supervision can be an important means to socialize PhD candidates into responsible research practices. Yet how is responsible supervision understood from different perspectives, and how do you create an atmosphere of psychological safety where dilemmas and mistakes can be openly discussed? Dr Haven will give an overview of the literature on responsible supervision, highlight some case studies, and close with some work-in-progress results from recent focus groups with PhD candidates and supervisors intended to explore responsible supervision in the context of responsible research.

Session:
Women of MathPsych Professional Development Symposium

Detecting single-trial cognitive events in EEG using hidden semi-Markov pattern analysis and the HMP python package

Borst, Jelmer
University of Groningen

Van Maanen, Leendert

Utrecht University, The Netherlands

Weindel, Gabriel
University of Groningen, The Netherlands

Session:
Workshop: Detecting single-trial cognitive events in EEG using hidden semi-Markov pattern analysis and the HMP python package

In this workshop, participants will learn how to use hidden semi-Markov pattern analysis (HMP, Anderson, Zhang, Borst, &; Walsh, 2016) to detect cognitive stages on a by-trial basis in EEG data. HMP combines hidden semi-Markov models with multivariate pattern analysis to quantify the number of cognitive processes within a trial as well as estimate their durations on a single-trial basis. The workshop is decomposed into lectures about the method and tutorials. Tutorials will be based on a python implementation with new functionalities (see `https://github.com/GWeindel/hmp`) and will guide participants through all the possibilities offered by HMP. After this workshop, participants will be familiar with the method and the code, able to simulate data corresponding to their research question, fit HMP models to their data, analyse the resulting models and draw inferences on experimental and individual differences, and leverage their EEG analysis through by-trial estimates of cognitive events timing. The last lecture will allow participants to further think about how they can integrate HMP with cognitive and statistical models of behaviour.

Identifying context effect sweet spots: There's an app for that!

Cavagnaro, Daniel
California State University, Fullerton

Pettit, Elizabeth

Huang, Yu
University of Illinois at Urbana-Champaign

Johnson, Joe
Miami University

Regenwetter, Michel
University of Illinois at Urbana-Champaign

Session:
Symposium: Deterministic and Probabilistic Models of Choice

Context effects, wherein the introduction of a third option can seemingly alter the preference relation between two other choice options, are pervasive in decision making. While decades of research have supported their existence, there has been some difference in claims regarding exactly which occur, and under which circumstances. Two specific limitations of previous work may be preventing a fuller understanding of these behaviors: studies tend to use a few characteristic stimuli to test each effect, and they analyze results based on aggregate choice proportions. The former was remedied in a recent study by Dumbalska et al. (2020) in PNAS, which used 32 stimuli spanning a two-dimensional attribute space. We address the latter concern here. In particular, we demonstrate a novel and powerful way of investigating context effects, within subjects, based on relatively simple assumptions about individual choice patterns. The framework translates hypotheses about preference or indifference on each choice problem into probabilistic models characterized by inequality constraints on binary choice probabilities. While ostensibly these models form convex polytopes in a 32-dimensional space, which would seem computationally unwieldy, it turns out to be computationally efficient to calculate Bayes factors for their empirical performance by treating them as cross-products of line-segments. We offer an easy-to-use and openly available web application allowing other researchers to test, virtually instantaneously, their own sets of hypotheses on the data from Dumbalska et al. (2020).

Random ordering models and flow polytopes

Doignon, Jean-Paul
Universite Libre de Bruxelles

Saito, Kota
California Institute of Technology

Session:
Symposium: Deterministic and Probabilistic Models of Choice

Random ordering models (Block and Marschak, 1960) explain various data sets from a common assumption: the answers of the subject(s) are guided by a latent probability distribution on the set of all orderings of the alternatives (here, ordering means linear ordering). For instance, there are such models for binary choice, multiple choice and best/worst choice. Characterizing a probabilistic model means describing its set of predictions (see for instance Doignon, Heller and Stefanutti, 2018). In many cases, the predicted points of a random ordering model form a convex polytope. The vertices of the polytope are known (they bijectively correspond to the orderings). The characterization problem is then turned into the search of a description of the polytope by a system of equalities and inequalities.

Obtaining an efficient characterization of the binary choice model is deemed infeasible (if $P \neq NP$, see Fiorini, 2006; note that the binary choice polytope is known in operations research as the linear ordering polytope). To the contrary, a remarkable achievement of Falmagne (1978) provides an explicit characterization of the multiple choice model. Falmagne generalizes inequalities formulated by Block and Marschak (1960), and he then shows by recurrence on the number of alternatives that the resulting inequalities together with obvious equalities determine the multiple choice polytope (MCP). To derive an enlightening proof of Falmagne's Theorem, Fiorini (2004) assimilates the MCP with the flow polytope of some acyclic network. We further exploit Fiorini technique, and extend its applicability.

Apart from a recognition of the facets by Suck (2002), the geometric structure of the MCP was apparently not much investigated. We describe the adjacency of vertices and the adjacency of facets (Doignon and Saito, 2023). Our description of the edges of the MCP helps understand recent findings in economics papers such as Chang, Narita and Saito (2022) and Turansick (2022). As a matter of fact, Doignon and Saito describe the two adjacencies in the more general setting of flow polytopes of acyclic networks (the MCP is just a particular case). So, the results apply not only to the MCP, but also to three polytopes which Davis-Stober, Doignon, Fiorini, Glineur and Regenwetter (2018) introduced as extended formulations of the weak order polytope, interval order polytope and semiorder polytope (the prediction ranges of random models with other types of orderings, see for instance Marley and Regenwetter, 2017): in each of the three cases, they rely on a specific, acyclic network. We also show how Fiorini technique helps in the analysis of further random ordering models, in particular we improve the results of Barberá and Pattanaik (1986) on the multiple choice model with latent weak orders (this is on-going joint work with Kota Saito).

However, there is no reason that any random ordering model could be characterized in terms of the flows on an acyclic network. For instance, the best/worst choice model apparently requires other techniques. This is another story, still to be written (for a prologue, see the other presentation by the speaker at this meeting).

If You Only Saw What I Saw: Modeling Heterogeneous Experiences and the Description-Experience Gap

Adaryukov, James
University of Kansas

Cavagnaro, Daniel
California State University, Fullerton

Pleskac, Tim
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Session:
Symposium: Deterministic and Probabilistic Models of Choice

The decision-making literature has explored the idea of a Description-Experience Gap: that people overweight rare events when those events are described and underweight rare events when they are experienced. Some work establishing this gap has ignored the variability in choices between and within individuals, limiting the conclusions that can be drawn about preference differences between described vs. experienced gambles. Regenwetter and Robinson (2017) established how QTest could address these limitations, allowing users to implement a set of probabilistic choice models to conduct order-constrained hypothesis tests on the description-experience gap. However, their initial implementation ignored one key source of heterogeneity: experience. Here, we extend these probabilistic choice models to account for the heterogeneity of experience. We show how choice models that treat experienced proportions of outcomes as best guesses of their probabilities —i.e., of the objective probabilities that determine the likelihoods of experienced outcomes—can be more parsimonious than models that use those objective probabilities directly. We use this more extensive set of models to test for the description-experience gap and to identify its source.

(Ir)rationality of Moral Judgment

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Session:
Symposium: Deterministic and Probabilistic Models of Choice

Chaotic responses to Covid-19, political polarization, pervasive misinformation, and social unrest raise the question whether some or many individuals exercise irrational moral judgment. We provide the first mathematically correct direct test for transitivity of moral preferences. Transitivity, a core rationality criterion, is conceptually, mathematically, and statistically difficult to evaluate. We tested three parsimonious, order-constrained, probabilistic characterizations. Among 28 individuals, everyone satisfied the weak utility model, according to which an individual's choices are noisy reflections of a single transitive preference. Tightening the bounds on error rates in noisy responses yielded a poorly performing model. Everyone obeyed the general random utility hypothesis, according to which individuals' choices reveal uncertain, but transitive, moral preferences. Bayesian model selection favored such probabilistic transitive preferences, hence also the equivalent random utility hypothesis. The findings suggest that there is some order underlying the apparent chaos: Rather than presume widespread disregard for moral principles, policy makers may build on navigating and reconciling extreme heterogeneity compounded with individual uncertainty.

Linear extensions of a partial order and NaP preferences

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Session:
Symposium: Deterministic and Probabilistic Models of Choice

The conditions of completeness and transitivity and their violations are important in theories of preferential choice. NaP (necessary and possible) preferences try to disentangle their interplay. They are related to so called Richter Peleg representations of partial orders, where the order is represented by a vector of numerical functions instead of a single one. They consist of splitting a quasiorder (preorder) into two nested relations. Recently, a series of papers (e.g. Gialotta & Watson (2018, 2020)) gave generalizations of this concept. It turns out that these results are rather straightforward consequences of (generalizations of) Szpilrajn's theorem on the linear extensions of a partial order. In the present paper we investigate the set of linear extensions in order to clarify what is behind NaP preferences and their generalizations. In doing so a natural extension on probabilistic NaP preferences is suggested.

Improving Research Replicability with an Easy-to-Use App for Creating and Evaluating Deterministic and Probabilistic Models of Binary Choice

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Session:
Symposium: Deterministic and Probabilistic Models of Choice

Numerous deterministic and probabilistic choice models are available in academic literature. To promote cumulative science and inclusivity, enhancing the accessibility of these models for researchers, including those without formal modelling training, is essential. To this end, I will introduce an R-Shiny app specifically designed to assist researchers in translating both deterministic and probabilistic binary choice models into a unified mathematical representation. This unified representation is accomplished by deriving a minimal set of equalities and inequalities that embody the model's predicted relationship between choice probabilities. This representation enables researchers to evaluate a model's quality based on factors like logical consistency and parsimony before conducting lab studies and allocating resources. Moreover, the app offers methods to bridge the gap between deterministic and probabilistic models. It allows researchers to explore various probabilistic versions of deterministic models by incorporating psychologically meaningful sources of variability in choice probabilities. The app further simplifies the research process by automatically generating input files for in-depth model comparisons, eliminating the need for programming skills. Researchers can use these files to calculate Bayes factors and frequentist p-values in model comparisons, ensuring a thorough evaluation of competing models. Throughout the presentation, I will underscore the significance of providing user-friendly modelling tools in strengthening the replicability of research findings in the behavioral, social, and cognitive sciences.

The Chasm between Scientific and Statistical Inference Demonstrated by Lord's Paradox

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Session:
Symposium: Scientific Inference and Statistical Inference

Lord (1967) published a two page paper with simple data presented in a graph. He wished to show the absurdity of using ANCOVA, without good reason, to reach a scientific conclusion. The use of 'paradox' in the title misled people to think the use of ANCOVA might have been valid, so Lord (1969) published another two page paper to clarify. That did not end the confusion. Statisticians and causal theorists have been publishing long articles every few years since 1969 arguing that Lord was wrong (as would be the very many scientists who would agree with Lord), and arguing that ANCOVA could be justified for the data Lord presented. This history illustrates the divide between scientific inference and statistical inference, closely related to the difference between deduction (statistics) and induction/abduction (science). It is telling that not one of the many publications since 1969 have shown a model capable of generating the data shown in Lord's original paper and also justifying the ANCOVA conclusions. Rather theoretical arguments have been given that there ought to be one. Scientists of course build theories; their theories are approximations to reality but attempt to explain in the simplest way consistent with present and past data the primary causal mechanisms that are operating to produce the data. The many statisticians and causal theorists analyzing Lord's paradox since 1969 seem to have missed this point.

There is no such thing as "statistical inference"

Morey, Richard
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Session:
Symposium: Scientific Inference and Statistical Inference

In recent discussions about the replication crisis, statistical looms large; claims about the misuse of classical significance testing, lax statistical evidence standards, non-replication (defined in a variety of statistical ways), and meta-analysis — statistical inference from statistical inferences — all involve statistical inference in some way. This is not surprising, since statistical inference has become one of the main tools for scientists since Fisher made it popular in the early 20th century. Arguments over the "right" way of approaching statistical inference give it outsized importance. I argue that, in fact, we cannot make statistical inferences except in trivial cases, and that all meaningful scientific inferences are non-statistical in nature. There is no unique, or obvious, mapping between a statistical "inference" and a scientific one; unfortunately, scientists have largely offloaded responsibility for their scientific inferences onto statistical theories that were not meant for the job. This point is not really new (Fisher made it in attacking Neyman and Pearson in 1955), and researchers often pay lip service to it when convenient (e.g., quoting Box, 1976: "All models are wrong…"). Statistical inference should be regarded as a mechanism for generating useful toys (Hennig, 2020) to introduce scepticism into scientific inferences, and no more. This does not mean inferential statistics are mere descriptive statistics, but the primacy of inferential statistics in interpretation of scientific data must be questioned (see also Amrhein, Trafimow, & Greenland, 2019).

The Pros and Cons of Preregistration

Wagenmakers, Eric-Jan

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Session:
Symposium: Scientific Inference and Statistical Inference

Preregistration innoculates researchers against the myriad of biases that all humans inevitably succumb to: hindsight bias, confirmation bias, motivated reasoning, the bias blindspot, and many more. Without preregistration, researchers are not attended to the fact that they are cherry-picking among hypotheses or among likelihood functions. Without preregistration, the probability that an ESP researcher reports the absence of ESP is about as low as the probability that a mathematical psychologist reports that the data undercut their pet model and support that of their rival (has it ever happened?). As a Ulysses contract, however, preregistration may tie the researcher to the mast a little too tightly: when the data contain unexpected patterns this demands a different analysis than was originally foreseen, and the penalty of classifying the new analysis as "exploratory" is overly harsh. There is considerable promise in two alternative Ulysses contracts: analysis blinding and the mini-multi-analysts approach. The feasibility of these contracts will be discussed.

Cure the cause, not the symptoms: Pre-registration will not remediate the perverse academic incentive system

Matzke, Dora
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Session:
Symposium: Scientific Inference and Statistical Inference

The “crisis of confidence” in psychological research is fueled by concerns about the replicability of key results and the widespread use of questionable research practices, such as the selective reporting of significant results. The controversy has drawn widespread public attention and triggered a broad range of attempts to identify and remedy the factors that contributed to the crisis. Although the proposed recommendations vary considerably in focus, they often aim to restrict researchers’ degrees of freedom and analytic flexibility. In this talk, I argue that psychology’s reform movement cannot succeed in the absence of profound changes in the present academic culture and incentive system. As long as academic journals prefer strong claims and clean stories as opposed to the messy reality, and as long as funding agencies and universities make their decisions based on performance metrics valuing quantity over quality, researchers are unlikely to resist the temptation to take shortcuts, exaggerate claims, and aim for high-impact journals that place more emphasis on novelty than rigor.

On the Utility of Hypothesis Testing and the Principle of Parsimony

van Ravenzwaaij, Don
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Session:
Symposium: Scientific Inference and Statistical Inference

Recently, the argument has been made that “what is called testing may have its place in inference [. . .], but it actually is just one way of describing one’s belief with respect to the possible values of a parameter. Instead, we recommend estimation of the full posterior distribution [. . .].” (Tendeiro & Kiers, 2019). In this talk, I will argue why I believe in many cases statistical testing is a necessary precursor to parameter estimation. I will structure my talk along two main arguments: (1) the principle of parsimony; (2) the size of the effect depending on the specifics of the experimental set-up.

Domain-specific overall value effects on choice behaviors and eye-movements

Gluth, Sebastian
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Ting, Chih-Chung
University of Hamburg

Session:
Eye Movements

The impact of value difference on response times (RTs) is well established, but recent research has shown that RTs are lower when the overall value/intensity across all options is higher: choosing between two very attractive / high-intensity options leads to faster decisions than choosing between two less attractive / low-intensity options. Whereas the overall value effect on RT appears to be robust and generalized across various decision types, little is known about its effect on choice accuracy and eye movements. The present study investigates the computational mechanisms underlying the impact of the overall value of available options on decision-making. We used attentional drift-diffusion model (aDDM) to simulate decision-making under different levels of overall value, and found that the overall value was predicted to reduce choice accuracy (together with RT) regardless of choice domains. To test these predictions empirically, we conducted a 3 (OV: sum of option values/stimulus intensities) by 3 (VD: the difference between values/stimulus intensities) by 2 (choice domain: value-based and perceptual decision) within-subject design eye-tracking experiment with $n = 60$ participants. Remarkably, the results were partially consistent with the model predictions but suggested a high degree of domain-specificity of overall value effects. In particular, we found that accuracy rates were significantly lower at a medium OV level compared to high and low levels in the value-based decision only, while accuracy in perceptual decision was not significantly changed by overall value manipulation. With respect to eye-tracking, OV similarly affected fixation patterns across choice domains: middle and final fixation durations were significantly decreased from low to high OV. However, we observed that OV adjusted the relationship between the final fixation and the choice in value-based decisions only: the tendency of choosing the last fixated option (i.e., snack) was increased when OV was decreased. Together, our results suggest that overall value is involved in the choice process and different cognitive mechanisms are needed to capture domain-specific impacts of overall value on choice accuracy, final fixation bias and their interactions.

A model-based approach to parsing eye-movement data

Visser, Ingmar
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Session:
Eye Movements

Eye-tracking allows researchers to infer cognitive processes from eye movements that are classified into distinct events. Parsing the events is typically done by algorithms. Here we aim at developing an unsupervised, generative model that can be fitted to eye-movement data using maximum likelihood estimation. This approach allows hypothesis testing about fitted models, next to being a method for classification. We developed gazeHMM, an algorithm that uses a hidden Markov model as a generative model, has few critical parameters to be set by users, and does not require human coded data as input. The algorithm classifies gaze data into fixations, saccades, and optionally postsaccadic oscillations and smooth pursuits. We evaluated gazeHMM's performance in a simulation study, showing that it successfully recovered hidden Markov model parameters and hidden states. Parameters were less well recovered when we included a smooth pursuit state and/or added even small noise to simulated data. We applied generative models with different numbers of events to benchmark data. Comparing them indicated that hidden Markov models with more events than expected had most likely generated the data. We also applied the full algorithm to benchmark data and assessed its similarity to human coding and other algorithms. For static stimuli, gazeHMM showed high similarity and outperformed other algorithms in this regard. For dynamic stimuli, gazeHMM tended to rapidly switch between fixations and smooth pursuits but still displayed higher similarity than most other algorithms. Concluding that gazeHMM can be used in practice, we recommend parsing smooth pursuits only for exploratory purposes. Future hidden Markov model algorithms could use covariates to better capture eye movement processes and explicitly model event durations to classify smooth pursuits more accurately.

Improving Decision Making Models by Considering Attention Processes: The Gaze-Weighted Advantage Race Diffusion Model

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Hadian Rasanan, Amir Hosein
Shahid Beheshti University

Session:
Eye Movements

Considering the type of information that people pay attention to when making decisions and how long their attention lasts can improve the predictions of decision-making models. Previous research has demonstrated that options receiving the most attention during the decision-making process are typically the ones that are chosen. Additionally, more valuable options tend to receive more attention than inferior options. However, the interaction between these two effects is not yet fully understood. There are two possible ways in which attention and subjective value could interact: attending to an option could amplify its subjective value in a multiplicative way, or attention could increase its choice probability in an additive way. Although some studies suggest a multiplicative interaction between attention and value (Smith & Krajbich, 2019), others provide evidence for an additive interaction (Cavanagh et al., 2014). The attentional drift-diffusion model (aDDM) successfully explained the effect of attention by assuming a multiplicative interaction between attention and value (Krajbich et al., 2010). The model posits that when individuals pay attention to an option, the accumulation process for that option is amplified. More recently, the gaze-weighted linear accumulator model (GLAM) following aDDM has been suggested, which assumes independent accumulators for each option and uses the gaze percentage for each option instead of fixation duration (Thomas et al., 2019). Models that assume a multiplicative interaction between attention and value have the advantage that they can predict magnitude effects in decision making, where options with higher subjective values are chosen faster than those with lower values. The present study introduces the Gaze-weighted Advantage Race Diffusion (GARD) model, which simultaneously assumes both additive and multiplicative interactions between attention and value. We rigorously tested this new model on three existing datasets on human food choice by Krajbich et al. (2010), Smith and Krajbich (2018), and Chen and Krajbich (2016). Our results show that the GARD model outperforms existing models that assume only a multiplicative interaction between attention and value, indicating that it provides a more accurate description of people's decision-making processes.

Consequences of mature cognitive control systems

The choices we make in our everyday lives require us to (1) selectively attend to the contents of a stimulus, and (2) connect those contents to information in memory. When learning, these two mechanisms interact with one another in a dynamic, cyclical fashion over time. Here, we explore how these interactions can produce "learning traps" by comparing profiles of selective attention (through eye-tracking data) and choice between two groups known to have different memory capacities: adults and 4-5 year-old children. Although the data confirm that children are less susceptible to representation traps, we also show through computational modeling that the mechanisms that explain this difference are poorer working memory, and greater interest in learning about the dimensions of information themselves. It seems as though by elongating the maturation of selective attention and working memory, nature engineered a way for children to explore the world, helping them to avoid learning traps.

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Session:
Eye Movements

A theory of information search in multi-attribute decisions

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Session:
Eye Movements

Humans are confronted with a complex world, in which many choice situations are characterized by a large number of options described on multiple attributes. To meet this challenge, they must find a suitable trade-off between making informed decisions on the one hand and limiting invested resources such as time and effort on the other hand. We argue that humans achieve this balance by searching systematically for relevant information in an efficient and goal-directed, but not strictly optimal manner. More specifically, we propose a Bayesian cognitive model of information search in multi-attribute decisions. According to this model, the values of different attributes and options are represented as belief distributions that are updated by sampling information through the allocation of selective attention. A decision is made when the belief distribution of the currently best option is sufficiently higher than the distribution of all other options. The core element of our model is a myopic transition rule, according to which people plan one step ahead and allocate attention to an option's attribute that is most likely to reveal decisive information in favor of the associated option. As an emergent property of this transition rule, our model predicts that information search is driven by three factors: the weights of attributes, the uncertainty about attribute values, and the accumulated value of options. Simulations of the model demonstrate that our theory accounts for a rich body of empirical findings on attention-choice interactions in both binary and multi-alternative decisions. For example, the model predicts i) the positive correlation between attention to an option and choice probability, ii) the attraction search effect, according to which people are more likely to keep attending to initially promising choice candidates, and iii) the negative correlation of the Payne Index (which quantifies alternative- vs. attribute-wise search) with the dispersion of attribute weights. Taken together, our computational theory offers a unifying description of information search and choice dynamics in multi-attribute decisions and suggests that humans search in an adaptive and efficient but still not strictly optimal way.

Chronometric Psychophysics

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Matzke, Dora
University of Amsterdam

Heathcote, Andrew

Session:
Similarity and Perception

Despite the mapping between objective and subjective magnitudes being central to psychology's foundational discipline of psychophysics, quantitative characterisations that are stable across different individuals and contexts have remained elusive. We address this problem through a theoretical framework defining subjective magnitudes as the inputs to a dynamic model of perceptual two-alternative forced choice. Three observer-specific parameters—their sensitivity to subjective magnitudes, and differences between magnitudes, and their decision urgency, along with the psychophysical function mapping objective to subjective magnitudes—determine the rate at which evidence for each choice accrues. Responses and response times are a function of the evidence rate, additive stochastic noise, the threshold amount of evidence required to make a choice, and the time for non-decision processes. We develop both non-parametric and parametric methodologies within this framework to measure the psychometric function and apply them to judgements about which of two rectangles has a greater area of one of two colours. In almost every participant over several experiments varying the decision context (sets of stimuli spanning different ranges), both methodologies converge on an identity mapping between the objective proportional area and the subjective input to the decision process. Further experiments, looking at broader stimulus ranges and different decision tasks explored the limits of this unanimity.

A common representation of perceived intensity and the near-miss to cross-modal commutativity

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Session:
Similarity and Perception

We are able to compare the loudness of a tone to the brightness of a visual stimulus, and vice versa. This may be explained by the long-standing assumption of a common representation of perceived intensity that is shared by almost all modalities. Luce, Steingrimsson, and Narens (2010, Psychological Review, 117, 1247-1258) formalize this idea within a cross-modal version of the theory of global psychophysics, which can be empirically tested in a parameter-free way through the axiom of cross-modal commutativity of successive magnitude productions. The paper provides a theory-based analysis of data on this axiom collected by Ellermeier, Kattner, and Raum (2021, Attention, Perception, & Psychophysics, 83 , 2955-2967), which is grounded on a recently suggested extension of the global psychophysical approach to cross-modal judgments (Heller, 2021, Psychological Review, 128, 509-524). This theory assumes that stimuli are judged against respondent-generated internal references which are modality-specific and potentially role-dependent (i.e., sensitive to whether they pertain to the standard or the variable stimulus in the performed cross-modal magnitude production task). The analysis reveals a massive and systematic role-dependence of internal references. This leads to predicting small but systematic deviations from cross-modal commutativity, which are in line with the observed data. In analogy to a term coined in the context of Weber's law this phenomenon is referred to as near-miss to cross-modal commutativity. The presented theory offers a psychological rationale explaining this phenomenon, and opens up an innovative approach to studying cross-modal perception.

A Bradley-Terry-Luce model-based analysis of human perception and computer vision in identifying melanoma lesions

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Session:
Similarity and Perception

Melanoma is a deadly skin cancer, and early detection is critical for improving survival rates. Dermatologists typically rely on a visual scan to diagnose melanoma by assessing the primary perceptual characteristics of a skin lesion. The common ABCDE heuristic, for example, suggests observers check a lesion for shape (A)symmetry, (B)order irregularity, number of unique (C)olours, and (E)volution over time. Whilst this heuristic provides a practical guide, it is a limited approach. Firstly, all lesions vary and often contain only a subset of these features. Secondly, a combination of abnormal features can lead to a diagnosis, making the diagnostic process complicated and error-prone. Advanced computer vision algorithms (CVA) have emerged as a powerful approach to melanoma identification. CVAs can evaluate lesion features to generate highly accurate and objective assessments. However, despite CVA advancements, they can only be used in conjunction with an expert assessment. Thus, the perceptual expertise of dermatologists remains a critical component in the accurate and timely detection of melanoma. Our project aims to improve the early detection of melanoma by investigating the perceptual judgments of skin lesion colour and shape made by humans and comparing them with the feature representations generated by computer vision algorithms. We recruited non-expert participants online to complete a two-alternative forced-choice task using skin lesion images from the ISIC archive. Participants were instructed to choose the image that exhibited a greater frequency of unique colours in one condition and greater border regularity in another among the two images presented in a trial. We analysed the data using the Bradley-Terry-Luce (BTL) model to estimate each lesion image's relative "strengths" along these perceptual dimensions. We then compared these estimates to computer vision assessments of the same perceptual features. We discuss the methodological approach, preliminary results, and future directions.

Systems alignment in concept learning: evidence from children's early concepts and beyond

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Session:
Similarity and Perception

The standard view of learning - be it supervised, unsupervised, or semi-supervised - is event-based (e.g., a caregiver pointing to a dog and saying "dog"). However, recent work suggests that people also engage in a process called systems alignment in learning contexts.
It has been shown that similarity structures align across domains. For example, objects that are spoken about in similar contexts appear in similar visual contexts. This is a potential rich source of information that human leaners could exploit. Indeed, recent work demonstrates that humans make use of alignable signals when they are available, both to improve learning efficiency and to perform zero-shot generalisation.
Here, we present evidence which suggests that alignment processes could play a role in early concept acquisition. We find that children's early concepts form near-optimal sets for inferring new concepts through systems alignment. By analysing the structural features of early concept sets, we find that this is facilitated by their uniquely dense connectivity. We suggest that this is conducive to alignment because short-range semantic relationships are particularly stable. Feeding these insights from early concept acquisition back into a Machine Learning pipeline, we build generative models which leverage these key structural features to construct optimal knowledge states. The resultant concept sets demonstrate an improved capacity for learning new concepts.
Further inspired by these findings, we discuss the use of alignment-based priors for cross-modal learning in other Machine Learning systems, for example in the task of image classification.

Relating perception and memory for a novel set of reconfigurable auditory stimuli: a noisy exemplar approach

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Session:
Similarity and Perception

While many real-life events are complex and temporally extended, most memory research employs discrete, static stimuli. We begin to bridge this gap by developing a set of novel auditory stimuli constructed by adjusting the distribution of power across upper frequency bands. Across three studies, participants rated similarity between pairs of these sounds and engaged in a recognition memory task. We applied non-metric multidimensional scaling to similarity ratings to obtain a three-dimensional psychological representation of the stimuli. The first dimension appeared to correspond to timbral roughness and the second to timbral brightness, while the third did not admit a simple verbal label. There were also individual differences in the degree to which participants attended to each of these dimensions, potentially as a function of musical expertise, as well as encoding strategy, and personality variables such as conscientiousness. The representation inferred from similarity ratings predicted recognition memory performance for single probe sounds following sequential presentation of two sounds, consistent with similarity-based exemplar models of memory. Recognition false alarms increased with subjective similarity between the probe and the first memory item but not the second, suggesting that the most recent sound was represented in a form that is less susceptible to incidental similarity. We also observed a list homogeneity effect: hits and false alarms decreased with similarity between studied sounds. We build on these results to discuss implications for the development of an integrated theory of perceptual similarity and recognition memory in the auditory domain using a novel computational model that extends on elements from the exemplar-based random walk (EBRW; Nosofsky & Palmeri, 1997b) model. Model fits to behavioral data from the similarity rating and recognition tasks provide preliminary evidence for this theory.

Integrative neurocognitive approaches to understanding cognition through simultaneous analysis of EEG and behavioral data on single trials

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Session:
Symposium: Deep Learning for Cognitive Modeling

Cognitive neuroscience studies routinely concentrate on calculating the correlation coefficient between trial-averaged Event-Related Potentials (ERPs) and behavioral performance such as response time and accuracy. However there are some disadvantages in this traditional approach: 1) ignoring the variance of EEG data across trials, 2) requiring a large number of participants to find robust inferences, and 3) a lack of formal cognitive models to explain cognition. In this work, we used the drift-diffusion model to decompose perceptual decision making to underlying latent variables to explain behavioral performance. This method assumes that participants make decisions based on the accumulation of evidence during the time until continuously hits one of two alternative bounds. We introduce new integrative neurocognitive models to predict and constrain both behavioral and electroencephalographic (EEG) data at the single-trial level concurrently. Our framework shows how N200 latencies and Centro-parietal Positivites (CPPs) can be used for the prediction of visual encoding time and drift rate parameters sequentially. Moreover, we quantified what proportion of EEG variance across trials is related to cognition and what proportion is related to measurement noise. We used a likelihood-free (simulation-based) approach in the context of deep learning to approximate the distribution of latent parameters. We showed the robustness of the models to model assumptions and contaminant processes as well as applied parameter recovery assessment to explore how well the models' parameters are identifiable. We fit models to three different datasets including EEG and behavioral data to test their applicability and reliability. This framework can conveniently be used for multimodal data simultaneously (e.g. single-trial fMRI, EEG, and behavioral data) to study perceptual decision making in the future.

Comparing Bayesian hierarchical models: A deep learning method with cognitive applications

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Session:
Symposium: Deep Learning for Cognitive Modeling

Bayesian model comparison permits principled evidence assessment but is challenging for hierarchical models (HMs) due to their complex multi-level structure. In this talk, we present a deep learning method for comparing HMs via Bayes factors or posterior model probabilities. As a simulation-based approach, its application is not limited to HMs with explicitly tractable likelihood functions, but also includes implicit likelihoods. Further, the computational cost of our method amortizes over multiple applications, providing new opportunities for method validation, robustness checks, and simulation studies. We demonstrate the ability of our method to accurately discriminate between non-nested HMs of cognition in a benchmark against bridge sampling. In addition, we present a comparison of four partly intractable evidence accumulation models that examines the utility of the recently proposed Lévy flight model of decision-making.

Neural superstatistics for bayesian estimation of dynamic cognitive models

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Session:
Symposium: Deep Learning for Cognitive Modeling

Mathematical models of cognition are often memoryless and ignore potential fluctuations of their parameters. However, human cognition is inherently dynamic. Thus, we propose to augment mechanistic cognitive models with a temporal dimension and estimate the resulting dynamics from a superstatistics perspective. Such a model entails a hierarchy between a low-level observation model and a high-level transition model. The observation model describes the local behavior of a system, and the transition model specifies how the parameters of the observation model evolve over time.
To overcome the estimation challenges resulting from the complexity of superstatistical models, we develop and validate a simulation-based deep learning method for Bayesian inference, which can recover both time-varying and time-invariant parameters. We first benchmark our method against two existing frameworks capable of estimating time-varying parameters.
We then apply our method to fit a dynamic version of the diffusion decision model to long time series of human response times data. Our results show that the deep learning approach is very efficient in capturing the temporal dynamics of the model. Furthermore, we show that the erroneous assumption of static or homogeneous parameters will hide important temporal information.

Fading memory, waning attention: Modeling output interference with a dynamic diffusion model

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Session:
Symposium: Deep Learning for Cognitive Modeling

A ubiquitous finding in memory research is that over the course of a recall or recognition test, memory performance declines. This phenomenon is referred to as output interference, reflecting the notion that it results from the interference of information recalled or encountered during test with subsequent retrieval. Indeed, there is a large body of experimental evidence indicating that the decline in memory performance is not simply due to a longer study-test gap or increasing fatigue. However, a limitation of previous studies is that the influence of interference versus attentional processes is typically inferred from the experimental context rather than measured directly. Moreover, performance is usually assessed across blocks of trials rather than single trials. Thus, the relative contribution and the exact trajectories of memory processes and attention in output interference remain unclear. We propose to address this open question with a dynamic diffusion model: The diffusion model is a popular cognitive model for the analysis of reaction times in binary decision tasks. In the context of recognition memory, it allows researchers to disentangle retrieval processes – such as the speed of information uptake as measured by the drift rate – from attention-related processes – such as the response criterion as measured by the boundary-separation parameter. By implementing the diffusion model in a recently proposed deep-learning based superstatistics framework, we can assess the dynamics of these parameters over the course of the memory test and, thus, directly measure the relative contribution of the associated processes to output interference. Applying this dynamic approach to empirical data, we show that both drift rate and boundary separation decline over the course of the test. Thus, the finding emphasizes the role of both interference and attention in the emergence of output interference in recognition memory. Moreover, it highlights the usefulness of the neural superstatistics framework for dynamic cognitive models.

Compressing Bayesian Inference with Information Maximization

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Session:
Symposium: Deep Learning for Cognitive Modeling

Amortized deep learning methods are transforming the field of simulation-based inference (SBI). However, most amortized methods rely solely on simulated data to refine their global approximations. We investigate a method to jointly compress both simulated and actually observed exchangeable sequences with varying sizes and use the compressed representations for downstream Bayesian tasks. We employ information maximizing variational autoencoders (VAEs) which we augment with normalizing flows for more expressive representation learning. We showcase the ability of our method to learn informative embeddings on toy examples and two real world modeling scenarios.

Evaluating the Generalizability of Diverse Models of Interference Effects

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Session:
Quantum and Context Effects

Uncertainty can lead to violations of both "rational" decision-making (Tversky & Kahneman, 1974) and the laws of classical probability (CP; Busemeyer et al., 2011). One type of violation – interference effects – occurs when a marginal decision distribution depends on the presence or absence of a preceding category judgment (Wang & Busemeyer, 2016). Interestingly, recent studies have shown that interference effects emerge under some preceding categorization conditions but not others, resulting in a critical asymmetry (Busemeyer et al., 2009; Wang & Busemeyer, 2016). Models based on the formalism of quantum probability (QP) provide a good accounting of this unusual pattern in the data (Busemeyer et al., 2009; Wang & Busemeyer, 2016). More recently, we have defined models based on CP augmented with ancillary mechanisms that can account for interference effects in the data, in general, but not necessarily the critical asymmetry (anonymous 1; anonymous 2). Given these varied resolutions to violations of CP, an important question warrants further investigation: what is the generalizability of these models and the efficacy of their mechanisms under conditions of novel stimulus types and decisions? In the current study, we probe questions about generalizability by using non-human-stimuli to control for the potential confounding effects of pre-existing associations with human faces within the categorization-decision paradigm used by Wang and Busemeyer (2016). We further assess the influence of bias on interference effects by leveraging a pre-existing bias based on preferences for sophisticated, in comparison to simplistic, mind-types (Almaraz et al, 2018; Dennett, 1996; Epley & Eyal, 2019; Waytz et al., 2010) and a resource allocation task with a clear link to mind-type preferences (Dennett, 1996; Waytz et al., 2010). We expect our study to identify the extent to which interference effects, along with the critical asymmetry, emerge in the new data reflecting a pre-existing bias, and to determine whether three proposed models (using quantum cognition, ACT-R, and a multinomial processing tree) can account for the new findings. Ultimately, we expect our study to inform the degree to which a set of current models of interference effects generalize for biased beliefs and, by extension, to provide insights into processes underlying interference effects in other contexts.

Contextuality and hidden variable models

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Session:
Quantum and Context Effects

Contextuality in systems of random variables has been originally formulated in quantum physics in terms of hidden variable models (HVMs). These formulations are contingent on the systems of random variables being consistently connected, which means that any two variables answering the same question in different contexts have the same distribution. Outside quantum physics, and specifically in systems of random variables describing behavioral phenomena, consistent connectedness is virtually never observed. This has necessitated, in the last decade, an extension of the notion of contextuality to arbitrary systems of random variables, resulting in the theory called Contextuality-by-Default. However, for inconsistently connected systems the possibility of interpreting contextuality in terms of HVMs is lost, and this is considered by some a major problem. It can be shown, however, that any inconsistently connected system can be recast as a consistently connected one, so that the two systems describe precisely the same empirical or theoretical situations, and they are contextual or noncontextual together. The consistently connected rendering of a system is amenable to formulation in terms of HVMs. The similarities of this formulation with and differences from the HVM representations of the traditionally considered quantum-mechanical systems elucidate the subtle interplay of the mathematical and the empirical in describing phenomena by systems of random variables.

Kujala, J.V., Dzhafarov, E.N., & Larsson, J.-A. (2015). Necessary and sufficient conditions for extended noncontextuality in a broad class of quantum mechanical systems. Physical Review Letters 115, 150401.

Cervantes, V.H., & Dzhafarov, E.N. (2018). Snow Queen is evil and beautiful: Experimental evidence for probabilistic contextuality in human choices. Decision 5, 193-204.

Dzhafarov, E.N. (2022). Contents, contexts, and basics of contextuality. In Shyam Wuppuluri and Ian Stewart (Eds). From Electrons to Elephants and Elections, The Frontiers Collection. pp. 259-286. Cham, Switzerland: Springer.

Where are the context effects?

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Session:
Quantum and Context Effects

Context effects, including attraction, similarity, and compromise effects, have been widely studied. These effects occur when choices among existing alternatives are impacted by adding new alternatives to the choice set. Sometimes the addition of a new alternative impacts the relative choice share (RCS) for one alternative compared to another. In other cases, adding a new alternative simply increases the absolute choice share (ACS) one alternative receives. Here we report a meta-analysis of all three effects asking how reliably, across 23 papers with 29,538 observations, these effects impact the RCS and ACS. The results revealed that these three context effects robustly impacted the RCS of an option. While the attraction and compromise effects only weakly impacted the ACS. Results further showed that the context effects depend on the configuration of attributes across the choice set, yet nearly all the studies to date have focused on a very specific configuration. Furthermore, simulations with leading choice models that predict context effects like MDFT and MLBA make very different predictions about how different configurations of attributes give rise to these effects. Altogether our results establish a great need to map out how these context effects change over a much larger configuration of alternatives.

Contextual Sensitivity in Naturalistic Multi-alternative Choice

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Session:
Quantum and Context Effects

Decades of research have been dedicated to understanding context effects (attraction, compromise, and similarity) in multi-alternative, multi-attribute choice. Most studies have used laboratory tasks with artificial stimuli. For example, choices among apartments with attributes represented numerically (i.e., 10 miles to work). However, when participants are shown more naturalistic stimuli (e.g., photos of apartments), the effects often disappear (Frederick, Lee, & Baskin, 2014). Thus, researchers have argued that context effects are an artifact of artificial stimuli and do not occur in naturalistic choices (Frederick et al., 2014; Yang & Lynn, 2014; Trendl, Stewart, & Mullett, 2021). However, the absence of context effects does not imply the absence of contextual sensitivity. Context-dependent behavior occurs whenever the evaluation of an option is dependent on the other options, often defined as a violation of simple scalability. We take a joint experimental and computational modeling approach to address whether naturalistic decisions demonstrate contextual sensitivity. One of the critical limitations for using computational cognitive models to study naturalistic decision making is that these models require quantitative representations of stimuli. In the past, obtaining representations of naturalistic stimuli has been challenging. I will describe how machine learning models can be coupled with cognitive models to overcome this limitation and help resolve the issue of contextual sensitivity in naturalistic multi-alternative choice.

Performance of the volatile Kalman filter in the reversal learning paradigm

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Heathcote, Andrew

Session:
Reinforcement Learning

The delta learning rule offers a simple but powerful explanation of feedback-based learning. However, normative theories predict that the learning rate should depend on uncertainty, which would allow for more efficient learning processes especially when environments are volatile, such as in the reversal learning paradigm. This paradigm consists of an acquisition phase, in which the participant learns some properties of the environment (e.g., reward probability of each choice option), is followed by the reversal phase, in which those statistical properties are switched. In two datasets, we previously demonstrated that the delta rule fails to capture the speed at which participants adapt to the reversal. A mechanism that allows the learning rate to vary as a function of the volatility of the environment could potentially provide a better account of learning behavior in this paradigm. Here, we studied whether the volatile Kalman filter (Piray and Daw, 2020) better accounts for empirical data in the reversal learning paradigm, and include tests of parameter recovery.

Measuring impulsivity using a real-time driving task and inverse reinforcement learning

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Session:
Reinforcement Learning

Impulsivity has been extensively studied in relation to mental disorders and maladaptive behaviors using self-report questionnaires and behavioral tasks. A persistent issue is that self-report and behavioral measures show weak correlations between each other, although they are supposed to tap the same construct. To address this problem, we devised a real-time driving task called the "highway task" that allows participants to exhibit impulsive behaviors, such as reckless driving, which may mirror real-life impulsive traits assessed by self-report questionnaires. We hypothesized that the highway task would provide impulsivity measures that are strongly correlated with self-report measures of impulsivity. As hypothesized, statistical evidence supported the correlation between the performance in the highway task and a self-report measure of impulsivity (i.e., the Barratt impulsiveness scale, $r = 0.46$). By contrast, measures of impulsivity from two traditional laboratory tasks (delay discounting and go/no-go tasks) did not correlate with BIS ($r = 0.01, 0.07$, respectively).
To infer subjective reward functions that underlie observed real-time behaviors in the highway task, we used an inverse reinforcement learning (IRL) algorithm combined with deep neural networks. The agents trained by IRL produced actions that resemble participants' behaviors observed in the highway task. IRL inferred sensible reward functions from participants' behaviors and revealed real-time changes in rewards around salient events (e.g., overtaking, a collision with a car ahead, etc.). The rewards inferred by IRL suggested that impulsive participants have high subjective reward values for irrational or risky behaviors. Overall, our results suggested that using real-time tasks with IRL may bridge the gap between self-report and behavioral measures of impulsivity, with IRL being a practical modeling framework for multidimensional data from real-time tasks.

It's not all about choices: the influence of response times on inferring other people's social preferences

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Session:
Reinforcement Learning

Humans are known to be capable of inferring hidden preferences and beliefs of their conspecifics when observing their decisions. While observational learning based on choices has been explored extensively, the question of how response times (RT) impact our learning of others' social preferences has received little attention. Yet, there is only limited potential for inferring the strength of preference (i.e., the confidence with which the person has made their choice or how likely they are to make the same choice again) from choices alone, and RT can provide critical information in this regard. Here, we propose an orthogonal design to investigate the role of both choices and RT in learning and inferring others' social preferences. In our lab study, participants ($n = 46$) observed other people's decision process in a Dictator Game, where the dictators were asked to choose between different monetary allocations. Choice and RT information was either hidden or revealed to participants in a 2-by-2 within-subject design. Behavioral analyses confirmed our hypothesis: trial by trial, observers were able to learn the dictators' social preferences when they could observe their choices, but also when they could only observe their RT. To gain mechanistic insights into these observational learning processes, we developed a reinforcement learning model that takes both choices and RT into account to infer the dictator's social preference. This model closely captured the performance and learning curves of observers in the different conditions. By comparing this model to a Bayes-optimal model, we show that while our participants' learning is close-to optimal when they can observe choices, they substantially deviate from optimality when they can only observe RT, suggesting that the underlying mechanisms are better captured by our approximate reinforcement learning model. Overall, our study proposes an innovative approach to investigate the role of RT in learning and inferring preferences and highlights the importance of considering decision processes when investigating observational learning.

"One step beyond...": Computational principles in social interaction

Speekenbrink, Maarten

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Session:
Reinforcement Learning

In social settings, the consequences of our actions typically depend on the actions of other agents. Successful outcomes then require agents to adapt their behaviour to each other. Planning under such mutual adaptation is a challenging computational problem. Circumventing this complexity, socially-ignorant reinforcement learning can, in principle, succeed in optimising behaviour in the long-run. But this works for the isolated case of repeated exposure to the same task with the same other agents. In reality we have limited exposure to such situations, and are more likely to encounter other agents in the same task, or encounter the same other agent in different tasks. Leveraging prior experience then requires generalization, from the same agent to other settings, and from encountered agents to novel agents. Such generalization can rely on various inferences, such as others' depth of strategic reasoning (e.g. how far to proceed with reasoning such as "you think that I think that you think that I will do...") and their social preferences (e.g. "you want us both to be better off" vs "you want to make sure you are further ahead of me"). Here, I will discuss some of the challenges of such social inference, present evidence that such inferences are indeed made, and provide a new framework (based on hidden Markov models) to navigate planning in social interactions.

Modeling response inhibition in the stop signal task: the copula approach

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Session:
Cognitive Control

The stop signal paradigm is a popular tool to study 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 subjects should withhold their response (stop task). The main interest for modeling is in estimating the unobservable stop-signal processing time, that is, the covert latency of the stopping process as a characterization of the level of response inhibition mechanism. In the dominant model performance is hypothesized as a race between two stochastically independent random variables representing go and stop signal processing (independent race model, IRM). Different of versions of the IRM including parameter estimation methods have been proposed, in particular classic non-parametric ones by G. D. Logan and colleagues and parametric ones by D. Matzke and colleagues. 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 of when a stop signal is presented after a certain time interval (stop signal delay, SSD). On the other hand, consistent violations of this prediction have been observed for certain SSD values (e.g., P.G. Bissett and colleagues). Here we propose non-independent versions of the race model based on the statistical concept of copula. Copulas allow one to study multivariate dependency separately from assuming specific marginal distributions. We investigate under what conditions these new race models are consistent with violations of the distribution inequality stated above.

Cognitive process modeling of context independence violations in the ABCD Study stop-signal task

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Session:
Cognitive Control

The stop-signal paradigm is a cornerstone of research on response inhibition and there is a rich history of formal cognitive models that explain individuals' behavior on the task. It is therefore not surprising that this task has been included as the primary measure of response inhibition in the Adolescent Brain Cognitive Development (ABCD) Study, a longitudinal neuroimaging study of unprecedented scale that is in the process of following over 11,000 youth from middle childhood though age 20. However, the ABCD Study's unique task design involves a visual stop-signal that replaces the choice stimulus, creating a masking effect that impedes information processing on trials with short stop-signal delays. As this design feature violates the critical "context independence" assumption shared by most current methods for estimating stop-signal reaction time (SSRT), some experts have called for the task to be changed or for previously collected ABCD data to be used with caution. We present a cognitive process modeling framework that provides a parsimonious explanation for the impact of this design feature by combining prior insights on the effects of visual masking on choice evidence accumulation with recent "hybrid" racing-diffusion ex-Gaussian (RDEX) approaches to modeling the stop-signal task. We demonstrate that the resulting model, RDEX-ABCD, successfully accounts for key behavioral trends in ABCD data, including the inhibition function and the impact of context independence violations on choice accuracy rates. Simulation studies using this model suggest that failing to account for context independence violations in the ABCD design can lead to erroneous inferences in several realistic scenarios. However, RDEX-ABCD effectively addresses these violations and can be used to accurately measure the timing of response inhibition processes and additional mechanistic parameters of interest. More broadly, results demonstrate the feasibility of addressing context independence violations by building process-based explanations for them into models of the stop-signal task.

Stop-Signal Reaction Time Largely Reflects Sensory and Motor Delays

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Session:
Cognitive Control

The stop-signal reaction time (SSRT) is often interpreted as capturing people's cognitive ability for rapidly and flexibly inhibiting prepotent actions when not desirable anymore. Its calculation is designed to circumvent the effect of strategy on baseline speed in the hope to specifically isolate the speed of signals conceived as reactive, top-down and inhibitory. However, the ability to act upon any signal, be it by producing or withholding a response, also always depends on i) when the information becomes available within decision areas, i.e. sensory delay, and ii) how long actions take to be executed (because only actions still in the planning stage can be withheld, and only executed actions are observable behaviourally). In line with (i), SSRT is clearly influenced by stop-signal contrast. In line with (ii), manual SSRT is also clearly longer than saccadic SSRT. In recent work (https://www.biorxiv.org/content/10.1101/2023.02.20.529290v1), we showed that the sum of (i) and (ii), i.e. non-decision time, is directly measured by the dip onset time (the earliest time point where the signal-absent and signal-present RT distributions depart). Importantly, this measure is immune to top-down factors, including whether the task is to stop or ignore the signal. Predictably, we show that individual differences in manual and saccadic SSRT are correlated with dip onset time (all $r > 0.5$ across datasets). This result is consistent with individual differences in SSRT largely reflecting sensory and/or motor influences, rather than being a pure measure of top-down inhibition speed. Alternatively, there may also be genuine correlations within the population between, on the one hand, the speed of bottom-up and/or motor signals and, on the other hand, the speed of top-down signals. Either way, this result calls for a reconsideration of past conclusions drawn from the use of SSRT (554 articles according to pubmed on the 29th of March, 2023), in particular studies reporting changes in SSRT in relation to clinical conditions, drugs, age, personality traits, general intelligence, brain structure, brain function, genes or performance on other tasks. Our results open the possibility that within and between-individual differences in SSRT, so far interpreted as differences in top-down control abilities, largely reflect variations in sensory delay and/or motor output time.

The neutral condition in conflict tasks: the implications of neutral condition RT behavior on modeling

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Ulrich, Rolf

Session:
Cognitive Control

While the relation between congruent and incongruent conditions in conflict tasks has been the primary focus of cognitive control studies, the expectation of neutral condition behavior is oft ignored, or set as directly between the two conditions. However, empirical evidence suggests that average neutral reaction time (RT) contradicts this assumption. The present studies, thus, sought to, first, reinforce the informative nature of the neutral condition and, second, to highlight how it can be useful for modeling. To do this, we first explored how RT in the neutral condition of conflict tasks (Flanker, Stroop, and Simon Tasks) deviated from the predictions of current diffusion models.
Many of the deterministic versions of cognitive conflict models predicted a neutral RT that is the average of the congruent and incongruent RT, called the midpoint assumption. This assumption is maintained over the time course, resulting in the parallel assumption. To investigate these assumptions, we first conducted a limited literature search that recorded the average RTs of conflict tasks with neutral conditions. Upon finding evidence of a midpoint assumption violation with smaller RT differences between the congruent and neutral conditions, we tested the prior mentioned conflict tasks with two different, distinct sets of stimuli.
The results suggested that a violation of the midpoint assumption is present in different manners depending on the conflict task and the stimuli. Then, a follow up study was performed in order to test the parallel assumption via the Speed-Accuracy Tradeoff paradigm. From the results, clear violations of the parallel assumption were observed in all three conflict tasks. Due to the implications of these violations, the authors then suggested possible elaborations of the Diffusion Model of Conflict to account for these phenomena.

Order constrained modeling and inference in psychology and law

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Session:
Statistics: Order Constraints

There is much debate, in the field of Psychology and Law, about race effects and racial bias in legal contexts. Many studies report that people display favoritism towards suspects with light skin over suspects with dark skin. Other studies report the opposite effect, where participants give disproportionately favorable judgments and trial outcomes to suspects of color (see Mitchell et al., 2005 for a full meta-analysis). Such conflicting findings provide an ideal opportunity for model competition.

We introduce order-constrained modeling to the field of Psychology and Law. Specifically, we model participants' decisions when put in the role of an interrogator questioning a suspect. We formed a set of 28 mathematical models by taking a series of verbal hypotheses and translating them into order constraints on Binomial parameters. The hypotheses are informed by various research in Psychology and Law regarding how people's initial guilt judgments about others might affect later decisions (O'Brien, 2009), how tattoos on a suspect could affect observers' judgments (Brown et al., 2018), and how the race of a suspect might impact the decisions people make about the suspect (Mitchell et al., 2005). Order-constrained modeling allows us to distinguish very specific, nuanced predictions about how these factors might impact people's decision making. It also allows for combinations of predictions about the impacts of these factors to be tested jointly, in a single statistical test.

We also consider novel mixture models that can capture two sub-populations with different race effects. These mixture models provide an opportunity to explore race-related effects in a new light. We pit all competing hypotheses against each other and test them using our lab's software, QTEST (Regenwetter et al., 2014; Zwilling et al., 2019).

Incorporating the Luce-Krantz threshold model into the cultural consensus theory for ordinal categorical data: A simulation study

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Session:
Statistics: Order Constraints

Cultural consensus theory (CCT), developed by Batchelder and colleagues in the mid-1980s, is a cognitively driven methodology to assess informants' consensus in which the culturally "correct" (consensus) answers are unknown to researchers a priori. The primary goal of CCT is to uncover the cultural knowledge, preferences, or beliefs shared by group members. One of the CCT models, called the general Condorcet model (GCM), deals with dichotomous (e.g., true/false) response data which are collected from a group of informants who share the same cultural knowledge. We propose a new model, called the general Condorcet-Luce-Krantz (GCLK) model, which incorporates the GCM with the Luce-Krantz threshold theory. The GCLK accounts for ordinal categorical data (including Likert-type questionnaires) in which informants can express confidence levels when answering the items/questions. In addition to finding out the consensus truth to the items, the GCLK also estimates other response characteristics, including the item-difficulty levels, informants' competency levels, and guessing biases. We introduce the multicultural version of the GCLK that can help researchers detect the number of cultures for a given data set. We use the hierarchical Bayesian modeling approach and the Markov chain Monte Carlo sampling method for estimation. A posterior predictive check is established to verify the central assumptions of the model. Through a series of simulations, we evaluate the model's applicability and find that the GCLK performs well on parameter recovery.

Scoring functions in the setting of ordered qualitative scales

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Session:
Statistics: Order Constraints

Many decision making problems involve the use of linguistic information collected by questionnaires based on ordered qualitative scales. In such cases it is relevant how agents perceive the scales. Some of them can be considered as non-uniform, in the sense that agents may perceive different proximities between consecutive terms of the scale. For instance, in the framework of health-care and medicine, the ordered qualitative scale {poor, fair, good, very good, excellent}, used by patients to evaluate self-rated health, it could be considered as non-uniform if 'fair' is perceived closer to 'good' than to 'poor', or if 'good' is perceived closer to 'very good' than to 'fair', or if 'very good' is perceived closer to 'good' than to 'excellent'.
In order to facilitate the decision-makers to manage this ordinal information, we propose to assign numerical scores to the linguistic terms of ordered qualitative scales by means of several scoring functions. In this contribution we have introduced and analyzed several scoring functions. They are based on the concept of ordinal proximity measure that properly represents the ordinal proximities between the linguistic terms of the ordered qualitative scales.

Order-constrained Inference: A Nuanced Approach to Hypothesis Testing

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Session:
Statistics: Order Constraints

Many statistical analyses performed in psychological studies add extraneous assumptions that are not part of the theory. These added assumptions could adversely influence the conclusions one derives from the analyses. Order-constrained inference allows researchers to avoid unnecessary assumptions, translate conceptual theories into direct testable hypotheses, and run competitions among competing hypotheses. On top of these advantages, this reanalysis highlights how one can use order-constrained modeling to formulate more nuanced hypotheses at the item level and test them jointly as one single model. The data set comes from Pennycook, Bear, Collins and Rand (2020). The authors hypothesized that attaching warnings to a subset of fake news headlines increases the perceived accuracy of other headlines that are unmarked. Moreover, they also expected this effect to disappear when attaching verifications to true headlines. Using the QTEST software (Regenwetter et al., 2014; Zwilling et al., 2019), we assessed these hypotheses jointly across all individual headlines. To further leverage order-constrained inference, we ran a competition among competing hypotheses using Bayesian model selection methods. We observe that order-constrained inference not only provides us with a coarse view of all the hypotheses at the aggregate level, it also offers a fine-grained perspective of all the hypotheses at the item level.

Anticipating or merely characterizing change: How well do early warning signals work in more complex and chaotic regimes?

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Session:
Symposium: Complex Systems Analysis in Mental Health Research

Early warning signals (EWS) are used widely across fields such as ecology and virology to anticipate transitions like lake biodiversity changes and virus dissemination, and have recently shown promise as signals for mental health transitions. The statistical signals indicating an upcoming transition are often mathematically derived from dynamical system models, such as increases in variance as a marker of critical slowing down. As of yet, EWS have largely been applied to simple transitions such as the saddle-node bifurcation, yet it is widely conjectured that more complex transitions occur within systems as non-linear and high-dimensional as those found within psychopathology. To narrow this gap, we compare the performance of generic EWS in characterizing and anticipating more complex, higher-dimensional transitions between different dynamical regimes. In a numerical study of a four-dimensional Generalised Lotka-Volterra model under varying observational noise intensities, we focus on a noisy, periodic, and chaotic regime, which are traversed by two types of transitions: the birth of a limit cycle in a Hopf bifurcation and the creation of a chaotic attractor via a period-doubling cascade. Our simulation study approximates Ecological Momentary Assessment data collection, where data may be analysed in real-time without access to the full timeseries to detect a transition. In addition, to address the challenges arising in the move from theory to real-world psychological data, such as high dimensionality, non-linearity, noise, and non-stationarity, we include a relatively unexplored method in the EWS literature, namely Recurrence Quantification Analysis (RQA). RQA is a popular model-free nonlinear timeseries method which identifies recurrent patterns in line structures of the timeseries' distance matrix. Our study emphasizes the limitations of EWS with respect to more complex transitions: Do these measures anticipate upcoming changes or merely characterize the regime change that has already occurred?

Early Warning Signals in psychopathology

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Session:
Symposium: Complex Systems Analysis in Mental Health Research

Early warning signals are indicators that some (major) change is about to happen. In almost all situations the indicators are obtained from (multiple) time series. Research into such indicators in climatology and engineering has met with some success. Such indicators of large changes in mental health would obviously be useful in psychopathology. However, it has been shown that simply applying standard techniques for indicators of large changes to any kind of system will often fail, i.e., it may fail to indicate a change when it is coming, but more often it will indicate change when it is not coming. To avoid such mistakes in early warning signals, we propose a framework using network theory to determine the type of indicators of large (qualitative) changes in psychopathology. In this framework we require assumptions about the type of network (relations between variables) and how the network is affected by external influences (big and small events in life). Applying this framework narrows down the type of indicators that are useful to function as early warning signals. We then focus, using the network framework, to determining extreme values. There are strong connections between the fields of extreme value theory and dynamical systems. The connections between these fields can be used to obtain early warning signals.

Improving Treatments for Panic Disorder using Computational Modeling

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University of Amsterdam

Session:
Symposium: Complex Systems Analysis in Mental Health Research

Panic disorder is a highly prevalent mental health condition that significantly impacts patients' quality of life. However, current treatments are not universally effective and have shown limited improvement since their introduction decades ago. This lack of progress is due in part to our incomplete understanding of the system underlying panic disorder and how different treatments intervene on it. Existing theories suggest that this system comprises multiple components that interact in non-linear ways over different time scales. Because of the counter-intuitive behavior of such systems, verbal theorizing can only provide limited understanding about them. To address this issue, we extended an existing computational model of panic disorder with a typical Cognitive Behavioral Therapy (CBT) treatment. Simulating treatment outcomes allows us to study how different treatment components interact with each other. Based on this analysis, we develop a new CBT treatment and demonstrate that its simulated outcomes are superior. Next, we introduce inter-individual variation in key parts of the model, and study which treatment work best for which type of patients, which leads us to personalized treatment plans. We close by discussing how computational models can advance treatment research and may lead to the development of better and more personalized treatments.

The geometry of synchronisation: Quantifying the coupling direction of physiological signals within and between individuals using inter-system recurrence networks.

Hasselman, Fred
Radboud University

Session:
Symposium: Complex Systems Analysis in Mental Health Research

The measurement of physiological signals using wearable sensors (heart rate, electrodermal activity, skin temperature) as well as motor activity, has become a reliable, nonintrusive and affordable method for monitoring e.g. general arousal and physical activity. In a clinical context, such measurements may provide a useful tool in the care of patients who are unable to verbally report on their current emotional or psychological state. In the present study we analyse multivariate physiological time series that were simultaneously recorded in dyads of caregivers and youth with severe mental disability in residential care. We investigate whether synchronization between physiological signals can be used to predict incidents that occur during the day, which often concern some form of aggression towards objects, self, or others. So-called Inter-system Recurrence Networks (ISRN, an extension of Cross Recurrence Quantification Analysis) can be used to determine whether a coupling direction exists between the physiological signals of caregiver and client networks. This gives insight in leading, following or bi-directional interactions of physiological signals, within and between dyad members. Such synchronization measures may serve as early warning signals of incidents and could serve as indicators for interventions to prevent incidents (e.g. take a break, disengage, change of context). We compare our results to ISRN based on simulations of delay-coupled dynamic system models.

Optimal Allocation of Time in Risky Choices under Opportunity Costs

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University of Basel

Mullett, Tim

Stewart, Neil

Session:
Risky Choice

In economic decision-making there is a fundamental trade-off between deliberation time to make a good decision and opportunity costs of other rewarding activities. Recent theories analyzed how the optimal strategy of evidence accumulation for this problem depends on the environment. If the utility difference between two options is known a priori, deciders should accumulate evidence according to a drift-diffusion model with constant decision boundaries, if this difference is unknown beforehand collapsing boundaries should be used. Further, the exact position of the boundaries depends on the opportunity costs. However, little is known about whether people use these strategies adaptively. Here, we used a new data visualization to find signature patterns of behavior for optimal strategies. We then conducted two experiments, where participants rated and chose between risky lotteries, while we varied prior information and opportunity costs. We found that while participants were sensitive to opportunity costs, they failed to stop deliberation about their choices fast enough when no information about the utility difference of two lotteries was available. We discuss how this suboptimality can make participants spend too much time on problems where there is little to gain in real-world scenarios. Hence, whereas prior research focused on biases from utility maximization, we show that when taking opportunity costs into account, deciders can be too eager to maximize utility in an isolated choice problem.

Mathematical modeling of risk-taking in bipolar disorder: Evidence of reduced behavioral consistency, with altered loss aversion specific to those with history of substance use disorder

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Pleskac, Tim
University of Kansas

Burton, Cynthia
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University of Michigan

Taylor, Stephan
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Session:
Risky Choice

Bipolar disorder (BD) is associated with excessive pleasure-seeking risk-taking behaviors that often characterize its clinical presentation. However, the mechanisms of risk-taking behavior are not well-understood in BD. Recent data suggest prior substance use disorder (SUD) in BD may represent certain trait-level vulnerabilities for risky behavior. This study examined the mechanisms of risk-taking and the role of SUD in BD via mathematical modeling of behavior on the Balloon Analogue Risk Task (BART). Three groups—18 euthymic BD with prior SUD (BD+), 15 euthymic BD without prior SUD (BD–), and 33 healthy comparisons (HC)—completed the BART. Behavior was modeled using four competing hierarchical Bayesian models. Model comparison results favored the Exponential-Weight Mean-Variance (EWMV) model, which encompasses and delineates five cognitive components of risk-taking: prior belief, learning rate, risk preference, loss aversion, and behavioral consistency. Both BD groups, regardless of SUD history, showed lower behavioral consistency than HC. BD+ exhibited more pessimistic prior beliefs (relative to BD– and HC) and reduced loss aversion (relative to HC) during risk-taking on the BART. Traditional measures of risk-taking on the BART detected no group differences. These findings suggest that reduced behavioral consistency is a crucial feature of risky decision-making in BD and that SUD history in BD may signal additional trait vulnerabilities for risky behavior even when mood symptoms and substance use are in remission. This study also underscores the value of using mathematical modeling to understand behavior in research on complex disorders like BD.

The multiple attentional roots of probability weighting in risky choice

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Zilker, Veronika
TUM School of Management

Session:
Risky Choice

Probability weighting is one of the most powerful theoretical constructs in formal descriptive models of risky choice and constitutes the backbone of cumulative prospect theory (CPT). Probability weighting has been shown to be related to two facets of attention allocation: one analysis showed that differences in the shape of CPT's probability-weighting function are linked to differences in how attention is allocated across attributes (i.e., probabilities vs. outcomes); another analysis (that used a different measure of attention) showed a link between probability weighting and differences in how attention is allocated across options. However, the relationship between these two links is unclear. We investigate to what extent attribute attention and option attention independently contribute to probability weighting. Reanalyzing data from a process-tracing study, we first demonstrate links between probability weighting and both attribute attention and option attention within the same data set, the same measure of attention, and the same analytical framework. We then find that attribute attention and option attention are at best weakly related and have independent and distinct effects on probability weighting. Moreover, deviations from linear weighting mainly emerged when attribute attention or option attention were imbalanced. Our analyses enrich the understanding of the cognitive underpinnings of preferences and illustrate that similar probability-weighting patterns can be associated with very different attentional policies. This complicates an unambiguous psychological interpretation of psycho-economic functions. Our findings indicate that cognitive process models of decision making should aim to concurrently account for the effects of different dimensions of attention on preference. In addition, we argue that the origins of biases in attribute attention and option attention need to be better understood.

Modelling the influence of situational uncertainty on risk taking in everyday life

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Frey, Renato
University of Zurich

Session:
Risky Choice

Individuals make countless decisions that involve evaluating uncertain outcomes every day. The resulting behavior, often referred to as risk taking, has been studied for decades, with a strong focus on trait-like predictors of interindividual differences, such as the construct of risk preference. Yet, about 50% of variance in individual's risky choices cannot be explained with stable predictors, thus raising the question what situational factors affect risk taking. With the current study, we investigate one potential mechanism causing variation in risk taking between different choice-situations, specifically the perception of uncertainty. Individuals intuitively distinguish epistemic uncertainty, referring to lacking knowledge about the world, from aleatory uncertainty, caused by the innate randomness of the world. Previous laboratory research has found that people become increasingly risk-averse when their perception of uncertainty is more epistemic, rather than aleatory, however, it remains unclear if this tendency generalizes to real world decisions. We are tackling this shortcoming by tracking a person's decisions during their everyday life with an experience sampling study. This allows us to model participants' decision making throughout the day using Bayesian multilevel models, and show how different levels of epistemic uncertainty can predict risk taking. Additionally, we are collecting data on individuals' perception of situational uncertainty with a classic, yet often neglected method: Participants record think-aloud protocols, describing decision-situations as they experience them. With the resulting speech-data, we investigate two novel research questions. First, we use participants' verbal descriptions of choice-situations to quantify the degree of uncertainty an individual faces, and to thus predict variability in risk taking from these estimates. Second, we explore a relatively new way of using natural language data to model which features of a situation are relevant, salient, or accessible to individuals when making decisions. With that, we show how semantic information such as word embeddings can be used for inferring cognitive processes underlying risk taking, or other decision-processes.

Observational learning of Exploration Exploitation Strategies in Bandit Tasks

Danwitz, Ludwig
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Session:
Risky Choice

Situations requiring to balance exploration and exploitation are ubiquitous. In such, humans frequently have the chance to observe others. Participants performed restless nine-armed bandit tasks, either on their own or while seeing the choices of fictitious agents, which were equally good, but different regarding their tendency to explore. We used different Bayesian Mean Tracker models to fit participants data. Therein, individual choice probabilities are calculated from the expected values of all options using a softmax function, in which random exploration is implemented as temperature parameter while directed exploration biases the expected values of the options towards especially uncertain, informative options. We implemented copying in two different ways: in the unconditional copying model it is assumed that participants copy the observed agent with a fixed probability, independent of the subjective value estimations. In the copy when uncertain model, the probability of copying depends on the entropy in all options' value estimations. Our results indicate that the copy when uncertain model can account better for participants data than the unconditional copying model. Participants use observational learning directly, i.e., they imitate the specific choices, but they also accommodate their individual exploration strategy towards the strategy of the observed agents.

Connecting process models to response times through Bayesian hierarchical regression analysis

Behrens, Thea
Technical University Darmstadt

Jäkel, Frank

Session:
Bayesian Analysis

We propose a hierarchical Bayesian model that connects the counts of elementary processing steps from a process model with response times of individual participants in an experiment. We see our approach as bridging between the two fields of mathematical psychology and cognitive architectures. For models that are a bit simpler than GOMS (they need to be broken down into a count of one kind of processing step) we can make detailed response time analyses. We model each processing step as a draw from a Gamma distribution, so that for more elementary processing steps we expect both mean response time as well as variance to increase. We present two extensions of the basic model. We first extend the model to account for cases in which the number of processing steps is stochastic and unobserved. The second extension allows to work with several possible processing tactics and we don't know which tactics the participants use. From the distribution of response times it can thus be distinguished what kind of tactic was most likely used to which degree by each participant. We hope that our model will be a useful starting point for many similar analyses, allowing process models to be fit to and tested through detailed response time data.

A Hierarchical Signal Detection Model with Unequal Variance for Binary Responses

Lages, Martin
University of Glasgow

Session:
Bayesian Analysis

Gaussian signal detection models with equal variance are commonly used in simple yes-no detection and discrimination experiments whereas more flexible models with unequal variance require additional data and/or conditions. Here, a hierarchical Bayesian model with equal-variance is extended to an unequal-variance model so that it becomes applicable to binary responses from a random sample of participants. This appears to be at odds with conventional wisdom whereby parameters of an unequal-variance model are not identifiable if only binary responses are observed in a single condition. Although this holds true for non-hierarchical models, the present model assumes randomly and independently sampled discriminability and criterion values and approximately constant signal variance across participants. This novel unequal-variance model is investigated analytically, in simulations and in applications to existing data sets. The results indicate that the five population parameters correspond to five observable parameters of a bivariate sampling distribution and that model parameters can be reliably and accurately recovered or estimated if the sample size is sufficiently large. It is concluded that this approach provides a promising alternative to the ubiquitous equal-variance model.

An Examination of Hierarchical Bayesian Dynamic Structural Equation Models in Stan

Snijder, Jean-Paul
Heidelberg University

Pratz, Valentin

Schubert, Anna-Lena
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Session:
Bayesian Analysis

Dynamic Structural Equation Models (DSEMs) can be used to model complex multilevel relationships between multiple variables over time and have thus a wide applicability in many fields of psychological science. Mplus is a widely used and powerful software program for estimating DSEMs, but it has some limitations in terms of flexibility and scalability. To overcome these limitations, we have implemented the DSEM framework in Stan, a Bayesian modeling language which provides a flexible and efficient platform for developing complex models. Here we highlight the most important aspects from our upcoming tutorial paper: A theoretical introduction to DSEM, fitting a base-model (i.e., a bivariate lag-1 model) and some possible model extensions (i.e., latent variable modeling, mediation analysis), and finally a comparison between Mplus and Stan in functionality and parameter recovery. Overall, we want to present our tutorial as a clear and practical guide for researchers who want to take advantage of Stan as a powerful toolbox to specify and fit DSEMs.

Nothing and the seven priors. Re-analysis of data on Bayesian priors.

Biegler, Robert
NTNU

Brandtzæg, Ørjan Røkkum
Norwegian University of Science and Technology

Session:
Bayesian Analysis

Prior experience can help resolve ambiguity. Quantitative models of this process represent both prior experience and sensory information as probability distributions over suitable parameters. Such prior distributions are core features of models of perception, learning, and reasoning, and thus their properties are important.
If the problem to be solved is the estimation of an underlying cause that can be represented as a point value, then the Bayesian estimate of that point value involves multiplying the prior and sensory probability distributions. If the distributions are Gaussian, the precision of the resulting posterior is the sum of the precisions of the prior and the sensory distributions. If the posterior becomes the new prior, precision keeps adding up across iterations (this is known as the Kalman filter, and therefore we will call this the Kalman prior). That precision describes how precisely the mean of the underlying distribution is known.
A fundamentally different problem is predicting the distribution of future sensory data, useful for risk sensitivity and change point detection. In the long term, the variance of that prior should be the sum of the sensory variance and the variance of the generating process. That could be achieved by adding to memory a point value that represents the most recent sensory stimulus, then constructing a prior distribution from those point values. If instead it is assumed that each stimulus is represented as a distribution with sensory variance, and the prior is constructed by adding up all the distributions, then the variance of that prior will be the environmental variance plus twice the sensory variance. We call these priors the additive priors. Note that what is added to the prior is the sensory information or likelihood.
It is logically possible to derive a third family of priors by delaying storage in memory until after a posterior has been created through Bayesian cue integration of prior and sensory data to predict the distribution of future subjective experience (assuming that all subjective experience occurs after Bayesian cue integration). We call this the subjective prior. Again, it is possible to generate that prior either by adding (and renormalising) posterior distributions, or else by adding the central tendencies of posterior distributions. Because these posteriors are often skewed or multimodal, it matters whether central tendency is represented as mean, mode, or median, and we must examine all possibilities. Generating this family of priors alternates two operations: multiply prior and sensory data, then add the resulting posterior or its central tendency to the prior (and renormalise). Consequently, this family of priors is sensitive to the order of inputs, and it is impossible to know either the shape of the distribution or its variance without knowing in which order stimuli were presented. We note that these priors seem to have no statistically desirable properties whatsoever, but wish to examine them in case unknown constraints force organisms to use them. If so, their undesirable properties may have interesting implications.
We explain the properties of these different priors, and we are fitting models that use these priors to existing data from a study of memory for linear and angular displacement.
Preliminary analysis indicates that the worst performing prior is the Kalman prior, even though, in the papers we have found so far that explicitly state how the prior is updated, the Kalman prior is favoured 11 to 1.

Bayesian hierarchical modelling for between-subject analysis

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Gronau, Quentin
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Session:
Bayesian Analysis

Cognitive models are more and more frequently applied to test both within- and between-subject hypotheses, however, the latter has generally suffered from the lack of statistical methods to answer such questions. A common approach to testing between-subject hypotheses is to perform a second step of analysis on the estimated parameters of the model to answer whether, for example, drift rate differs with age, or between people with schizophrenia and controls. However, a lot of statistical power is lost in such two-step analyses. Here we propose to include linear models such as ANOVA, regression, and by extension mixed effect models, in the hierarchical framework in which cognitive models are usually estimated. With such a hierarchical linear model we omit the two-step analysis. Furthermore, we supply methods with which we can estimate Bayes factors between the null and the proposed model. Our work gives researchers the option to formalize different types of hypotheses for between-subject research, with the added benefit of maintaining a more parsimonious parameter space.

Cognitive modeling of category learning and reversal learning

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Session:
ICCM: Logic and Learning

During learning humans often test new hypotheses to infer causal relations between objects and actions. One very common example of learning is category learning in which humans learn to differentiate between different stimuli based on their features. The rational aspects of category learning in form of hypotheses testing need to be taken into consideration for improving computational models. Compared to reinforcement learning models that assume gradual learning, cognitive modeling allows to implement hypotheses testing and thus enabling steep transitions in learning. Here we extend our previously developed ACT-R model in a systematic way to further improve its fit to an auditory category learning and reversal learning experiment. For the initial category learning phase we optimized the model by enabling it two use two stimulus features right from the start. For improving the model's performance in the reversal phase, we introduced an additional mechanism of switching the motor-response for a given categorization. With these two changes we significantly increased the model's performance in our task. By comparing the backward learning curves of the participants to those of our model we observed that our model exhibits steep transitions during the initial category learning phase, a feature that reinforcement learning models have difficulties to reproduce.

Comparing Model Variants Across Experimental and Naturalistic Data Sets

Sense, Florian
InfiniteTactics, LLC

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Krusmark, Michael

Myers, Tiffany (Jastrzembski)
Air Force Research Laboratory

Session:
ICCM: Logic and Learning

Computational models of human memory have largely been developed in laboratory settings, using data from tightly controlled experiments that were designed to test specific assumptions of a small set of models. This approach has resulted in a range of models that explain experimental data very well. Over the last decade, more and more large-scale data sets from outside the laboratory have been made available and researchers have been extending their model comparisons to include such real-life data. We follow this example and conduct a simulation study in which we compare a number of model variants across a range of eight data sets that include both experimental and naturalistic data. Specifically, we test the Predictive Performance Equation (PPE)—a lab-grown model—and its ability to predict performance across the entire range of data sets depending on whether one or both of its crucial components are included in the model. These components were specifically designed to account for spacing effects in learning and are theory-inspired summaries of the entire learning history for a given user-item pair. By replacing these terms with a simple lag times (rather than full histories) or a single free parameter, we reduce the PPE's complexity.
The results, broadly speaking, suggest that the full PPE performs best in experimental data but that not much predictive accuracy is lost if the terms are omitted from the model when naturalistic data are concerned. A possible reason is that spacing effects are not very important in real-life data but very important in spacing experiments.

Extending counterfactual reasoning models to capture unconstrained social explanations

Droop, Stephanie
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Session:
ICCM: Logic and Learning

In contrast to rationalist accounts, people do not always have consistent goals nor do they always explain other people's behaviour as driven by rational goal pursuit. Elsewhere, counterfactual accounts have shown how a situation model can be perturbed to measure the explanatory power of different causes. We take this approach to explore how people explain others' behaviour in two online experiments and a computational model. First, 90 UK-based adults rated the likelihood of various scenarios combining short biographies with trajectories through a gridworld. Then 49 others saw each scenario and outcome, and verbally gave their best explanations for why the character moved the way they did. Participants generated a range of explanations for even the most incongruous behaviour. We present an expanded version of a counterfactual effect size model which uses innovative features (crowdsourced parameters and free text responses) that not only can generalise to human situations and handle a range of surprising behaviours, but also performs better than the existing model it is based on.

Modeling Change Points and Performance Variability in Large-Scale Naturalistic Data

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Session:
ICCM: Logic and Learning

To explain the performance history of individuals over time, particular features of memories are posited, such as the power law of learning, power law of decay, and the spacing effect. When these features of memory are integrated together into a model of learning and retention, they have been able to account for human performance across a wide range of both applied and laboratory domains. However, these models of learning and retention assume that performance is best accounted for by a continuous performance curve. In contrast to this standard assumption of models of learning and retention, other researcher have argued that ,over time, individuals display sudden
discrete shifts in their performance due to changes in strategy and/or memory representation. To compare these two accounts of memory, the standard Predictive Performance Equation (PPE; (Walsh, Gluck, Gunzelmann, Jastrzembski, & Krusmark, 2018)) and was compared to a Change PPE on fits to human performance in a naturalistic data set. We make several hypotheses about the expected characteristics of individual learning curves and the different abilities of the models to account for human performance. Our results show that performance that Change PPE was not only able to be better fit the data compared to the Standard PPE, but that inferred changes in the participant's performance was associated with greater learning outcomes.

Uncovering iconic patterns of syllogistic reasoning: A clustering analysis

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TU Chemnitz

Session:
ICCM: Logic and Learning

Syllogistic reasoning is one of the core domains of human reasoning research. Over its century of being actively researched, various theories have been proposed attempting to disentangle and explain the various strategies human reasoners are relying on. In this article we propose a data-driven approach to behaviorally cluster reasoners into archetypal groups based on non-negative matrix factorization. The identified clusters are interpreted in the context of state-of-the-art theories in the field and analyzed based on the posited key assumptions, e.g., the dual-processing account. We show interesting contradictions that add to a growing body of evidence suggesting shortcomings of the current state of the art in syllogistic reasoning research and discuss possibilities of overcoming them.

A diffusion model analysis of prior probability and spatial attention

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Miletić, Steven
University of Amsterdam

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University of Amsterdam

Session:
Evidence-Accumulation Models: Caution and Prior Probability

Spatial attention and prior probability manipulations have been shown to induce response biases in perceptual decision making behavior. Here, we study the interplay between spatial attention and prior probability manipulations. Participants completed a novel two-alternative forced choice task which simultaneously manipulates spatial attention and prior probability in a factorial design. The task features two cues which prompt the participant to attend to one side of the screen and to expect a given stimulus. A preliminary behavioral analysis showed strong influence of spatial attention and weak influence of prior probability on both RT and accuracy. We fit several variants of the diffusion decision model (DDM) to test which cognitive processes are affected by each manipulation. Preliminary results suggests that the prior probability manipulation affects the starting point parameter, and the attention manipulation the drift rate and non-decision times, in line with earlier literature. The results of this study will set the stage for an fMRI project investigating the neural underpinnings of spatial attention and perceptual expectation.

Hidden Markov Models of Evidence Accumulation in Speeded Decision Tasks

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Visser, Ingmar
University of Amsterdam

Session:
Evidence-Accumulation Models: Caution and Prior Probability

The evidence accumulation models (EAMs) are useful to study cognitive processes and their effects on response times and accuracy, capturing dependencies between the two. One phenomenon of interest is the speed-accuracy trade-off, where individuals sacrifice one for the other. Classical EAMs assume a continuous trade-off between speed and accuracy, thereby allowing performance to vary between guessing and (in principle) almost perfect responding.
However, alternative tradition of thinking suggests that participants may switch between distinct states rather than control the trade-off on a continuum. Hidden Markov Models (HMMs) are typically used to describe such behaviour, assuming two states - random guessing and stimulus-controlled states.
Typical HMM applications assume that speed and accuracy are independent of each other, conditioned on the states. However, evidence accumulation presumably takes place at the least under the controlled state, inducing a speed-accuracy trade-off within that state.
In this talk, we introduce a model that combines a HMM with an EAM that contains a discontinuous speed-accuracy trade-off on a larger scale (between states) and a continuous speed-accuracy trade-off on a smaller scale (within states), and show some applications on empirical data. We'll also discuss our experiences with a robust Bayesian workflow employed to validate the implementation of the model, and potential extensions to the model and its applications.

Explaining Fast Errors in Perceptual Decision Making: Starting Point Variability or Jumping to Conclusion?

Voss, Andreas
Heidelberg University

Session:
Evidence-Accumulation Models: Caution and Prior Probability

The diffusion model has become a standard model for perceptual decision making over the last decades. A challenge for cognitive models for this type of task is to model differences in mean reaction times for correct responses and error responses. In particular, for simple tasks with short response times, incorrect responses typically have lower mean response times than correct responses. In the diffusion model framework, this asymmetry is typically explained by variability in the starting point of the evidence accumulation process. Recently, the Levy-Flight model was introduced as an alternative explanation for fast errors based on jumps in evidence accumulation. In this talk, the goodness-of-fit of the Diffusion Model and the Levy-Flight Model is compared for different tasks.

The influence of catch trials on response caution – a diffusion model analysis

Lerche, Veronika
Kiel University

Janczyk, Markus

Session:
Evidence-Accumulation Models: Caution and Prior Probability

In typical response time tasks, catch trials are trials in which no stimulus is shown and participants accordingly do not have to respond. In previous studies, it has been assumed that stimulus expectancy–operationalized via the frequency of catch trials–affects response caution. For conditions with a higher proportion of catch trials enhanced response caution is expected. However, higher proportions of catch trials might also lead to less practice regarding the actual binary decision task, manifesting in reduced speed of information processing or longer encoding or motor execution times. By means of diffusion modeling we examine data from one of the studies that aimed at influencing response caution via a catch trial manipulation. Furthermore, we present data from a new study in which we systematically varied the proportion of catch trials. We consistently find longer non-decision times for conditions with higher proportions of catch trials, whereas the pattern is less clear-cut for drift rate and threshold separation. By means of a parameter recovery study, we further show that the effect in non-decision time is not driven by trade-offs in parameter estimation. In sum, the catch trial manipulation might be a questionable manipulation of response caution as it does not selectively influence threshold separation.

The speed-accuracy tradeoff for embodied decision making

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Session:
Evidence-Accumulation Models: Caution and Prior Probability

The theory of decision making has largely been developed as a disembodied open-loop process, however there is growing recognition that ecologically valid scenarios require integration of movement dynamics into current decision making theory, and a revision of what are considered to be core/fundamental decision components.
Here, we develop the theory of decision making by considering components which may be fundamental modulators of the decision making process, modelled as a bias on the accumulated evidence. Firstly, we consider this biased gain during evidence accumulation with respect to both the effects on movement dynamics and as a property of the egocentric frame with a causal influence on cognition, implying a stabilisation effect on both movement and neural activity; improving stability/convergence.
Secondly, we examine closed-loop embodied decision making in the context of optimality — it is generally accepted that open-loop decision making is optimised to maximise reward via some form of Bayes' Risk, prescribing a speed-accuracy tradeoff (SAT), and we therefore mediate between these models of decision making by exploring their influence on the SAT.
For closed-loop decision making, however, the form of the 'objective function' is unknown, and so finally, we consider a geometric heuristic in the form of a projection of the drift-diffusion model onto the situated decision space, as means of exploring optimality framed alongside higher level, ecologically inspired ideas of optimality, such as adaptability to moving targets or nonstationarity, to explore this fundamental aspect of embodied decision making.

The Affective Ising Model: A nonlinear model of affect dynamics

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Session:
Symposium: Computational Models in Affective Science

Computational models are often used to formalize and study fluctuations of affect over time. A central question to the creation of such models is which characteristics a computational model should possess in order to adequately describe affect dynamics. In this regard, evidence for the presence of nonlinearity in affect dynamics accumulates. However, it is not yet clear where this nonlinearity comes from: It might either represent an inherent characteristic of affect or it might be an artefact due to environmental effects. In this talk, I will present the Affective Ising Model (AIM) – a nonlinear model of affect dynamics – and detail several studies in which we compared its viability against linear competitor models. By accounting for external events in these studies, we were able to investigate whether the observed nonlinearity in affect is indeed due to external events, or due to affect being nonlinear in nature. Results from each study indicate that the AIM outperforms its competitors, even when accounting for external events. This suggests that nonlinearity is a defining feature of affect and should, consequently, be accounted for in our analyses. Submitted for the symposium "Computational models in affective science" with Kenny Yu, Alan Voodla, Lei Zhang, and Niels Vanhasbroeck.

AffectDDM – a computational perspective to affect generation in perceptual decisions

Voodla, Alan
University of Tartu / KU Leuven

Session:
Symposium: Computational Models in Affective Science

Decisions are often accompanied by feelings of positive or negative valence with some intensity, also called affect. It has been proposed that affect functions as a monitoring signal, recruiting subsequent regulatory control processes. However, it's unclear what are the mechanisms that generate affect in decision-making. Inspired by control process theory (Carver, 2015), we model affect as the difference between expected and actual progress in an evidence accumulation framework. Actual progress is mapped onto the drift-rate parameter and expected progress onto a novel expected drift-rate parameter during a perceptual decision. Affect is computed as the difference between the expected and actual amount of evidence in a trial. We then test predictions of this model in a perceptual decision-making experiment, where expected and actual progress are experimentally manipulated. We find that affect reflects the sum of actual and expected progress, but not their discrepancy as predicted by control process theory. Comparing the empirical data with model predictions, we find that the model is able to simultaneously account for choice, reaction times, and affect in perceptual decisions.

Multiple pathways to widespread fears: Disentangling idiosyncratic fear generalization mechanisms using computational modeling

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Zaman, Jonas
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Session:
Symposium: Computational Models in Affective Science

Human generalization research aims to understand the processes underlying the transfer of prior experiences to new contexts. Generalization research predominantly relies on descriptive statistics, assumes a single generalization mechanism, interprets generalization from mono-source data, and disregards individual differences. Unfortunately, such an approach fails to disentangle various mechanisms underlying generalization behavior and can readily result in biased conclusions regarding generalization tendencies. Therefore, we combined a computational model with multi-source data to mechanistically investigate human generalization. By simultaneously modeling learning, perceptual and generalization data at the individual level, we revealed meaningful variations in how different mechanisms contribute to generalization behavior. The current research suggests the need for revising the theoretical and analytic foundations in the field to shift the attention away from forecasting group-level generalization behavior and toward understanding how such phenomena emerge at the individual level. This opens the possibility of having a mechanism-specific differential diagnosis in generalization-related psychiatric disorders.

Multiple facets of social influence in goal-directed learning

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Institute for Systems Neuroscience

Session:
Symposium: Computational Models in Affective Science

One of the main challenges in social affective neuroscience originates from the fact that humans do not make decisions alone, but rather, are influenced by their social environment. However, few studies have inspected the underlying neurocomputational processes, in particular when learning from oneself and learning from others coexist in the same environment. Here, I will present a real-time multi-player goal-directed learning paradigm, where, within each group of five individuals, one participant was scanned with MRI. Leveraging reinforcement learning models and fMRI we captured nuanced distinction between direct valuation through experience and vicarious valuation through observation, and their dissociable, but interacting neural representations in the ventromedial prefrontal cortex and the anterior cingulate cortex, respectively, respectively. Connectivity analyses revealed increased functional coupling between the right temporoparietal junction (rTPJ) representing instantaneous social information and the putamen, when individuals made behavioral adjustment as opposed to when they stuck with their initial choice. Together, these data provide a comprehensive behavioral and neurocomputational mechanism of social influence in goal-directed learning and the potential associated social specificity.

Informative and efficient Bayesian hypothesis tests for lesion studies

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de Haan, Edward
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Wagenmakers, Eric-Jan

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Session:
Symposium: Bayesian Advances in Modeling Individual Differences

Experimental studies of brain lesions can reveal the neural underpinnings of behavior and inform theories of cognitive processes. But standard pre-post analysis methods used in lesion studies make an unnecessarily permissive assumption: They assume that some individuals' abilities will be better after lesions have been applied. This assumption is ethically and scientifically problematic: (1) it contributes to the pervasive low statistical sensitivity of lesion studies (wasting animal lives), and (2) it limits inferences to population averages when researchers are seeking insights that apply to each individual. These problems are exacerbated when researchers infer lesion-spared abilities from non-significant p-values.

We propose Bayesian hypothesis tests that incorporate constraints on individual differences and can quantify evidence of spared abilities. Our tests reflect researchers' substantive knowledge and appropriately constrain permissible outcomes: (1) carefully applied lesions impair each individual's ability and (2) the magnitude of impairment correlates with pre-lesion ability. As a result, our tailored Bayesian hypothesis tests (1) increase statistical sensitivity (saving animal lives), (2) warrant inference at the level of individuals, and (3) can quantify evidence for spared abilities.

In a series of simulation studies, we compare the performance of our tests with standard procedures. We quantify the gains in evidence and the resulting sample size savings for sequential designs. Of course, there is no free lunch. The increase in statistical sensitivity is the result of additional assumptions; violations of these assumptions can lead to biased inference. We explore the consequences of violating assumptions about response distributions and the structure of individual differences.

A framework to study individual differences in meaning representations

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Visser, Ingmar
University of Amsterdam

Sarafoglou, Alexandra
University of Amsterdam

Session:
Symposium: Bayesian Advances in Modeling Individual Differences

In experimental semantics, researchers are interested in the cognitive processes involved in language processing. The theory in this research area is highly formalized and rich, and usually embedded in formal logic. For instance, looking at the representation of quantifiers, formal logic predicts that the meaning of the quantifiers "more than half" and "most" are identical (i.e., more than 50% for two objects), that the meaning of these quantifiers is unambiguous, and consequently that all individuals will perceive these quantifiers in the same way.
While formal logic leads to precise theoretical predictions, a drawback is that it often fails to explain the richness of the observed data. Previous literature has found, for instance, that the quantifier "most" is associated with higher percentages than the quantifier "more than half," that the meaning of "most" is less precisely defined than "more than half," and that individuals vary considerably in their response pattern.
In this talk, we present a novel statistical model that captures individual differences in the representation of quantifiers. In addition, the model explains these differences by introducing cognitive processes to the theory such as thresholds, vagueness, and response error. We will illustrate our approach by applying our model to longitudinal data.

Bayesian hierarchical model approaches for disattenuating correlation in studies of individual differences

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University of California, Irvine

Rouder, Jeffrey
University of California, Irvine

Session:
Symposium: Bayesian Advances in Modeling Individual Differences

Recently, there has been a merger between experimental and differential Psychology where experimental tasks have been employed to probe individual differences. While this merger appears desirable, results have been problematic in two ways. First, correlations between tasks measuring the same construct are relatively low. For example, flanker and Stroop tasks are both assumed to measure the ability to inhibit the prepotent responses, yet performance on these tasks in the literature typically have correlations around .1 (Enkavi et al., 2019; Rey-Mermet, Gade, & Oberauer, 2018). Such low correlation values stand in contrast with findings in other domains where measures of abilities often have substantial positive correlations (Ritchie, 2015), a fact known as Spearman's positive manifold. These low correlations undoubtedly reflect low reliability leading to the well-known problem of attenuation. Following from this, the second way the merger has been problematic is that latent variable analyses tend to be unstable and unreplicable (Karr et al., 2019). Although there are methods of disattenuation, their resulting correlations are often too variable to provide meaningful insights (Rouder, Haaf, & Kumar, in preparation). To address the current predicament, we propose a new method of disattenuation that leverages the positive manifold by assuming it as a prior in a Bayesian hierarchical model. With this constraint, correlations may be disattenuated with reasonable precision, even in low-reliability experimental settings. We compare the performance of this approach to relatively unconstrained Bayesian hierarchical models (such as those with LKJ and Wishart priors) and the more conventional Spearman correction for attenuation.

Comparing and exploring modeling solutions to the reliability paradox in conflict tasks

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Matzke, Dora
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Session:
Symposium: Bayesian Advances in Modeling Individual Differences

The study of individual differences in cognitive control using conflict tasks such as the Stroop task has proven difficult. Despite robust experimental effects, the reliability of individual differences tends to be low, and correlations between tasks are weak at best. A statistical explanation for this reliability paradox is that individual differences are masked by trial-to-trial variability and are too small to be detected.
Modeling recommendations to improve the assessment of individual differences include the use of trial-level hierarchical models that account for trial noise, the use of descriptively more accurate models that account for the skewness of response time data, and the use of models that make cognitively more plausible assumptions, such as race or competitive models. At the same time, we may fall into the trap of overfitting.
In this talk, we will compare Bayesian hierarchical models of increasing complexity with respect to their signal-to-noise ratio, i.e., the ratio of the amount of "true" individual differences (i.e., the signal) to the trial-by-trial variability (i.e., the noise). This ratio has been proposed to indicate the degree of attenuation that can be expected in correlational research in the area of cognitive control (typically 1 to 7). By combining the most powerful modeling techniques and using progressively more complex models, can we optimize the signal-to-noise ratio and gain increasing resolution for individual differences?

Bayesian modeling approaches for individual differences in social cognition

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Session:
Symposium: Bayesian Advances in Modeling Individual Differences

Research in social cognition often relies on experimental tasks that generate responses in terms of accuracy and response times. Consider, for instance, the Implicit Association Test (IAT), which captures attitudes and stereotypes by measuring the strength of associations between concepts (e.g., race) and evaluations (e.g., good or bad) in a categorization task. In this task, based on cultural stereotypes, we expect responses to be faster and more accurate with white-positive / black-negative pairings than with black-positive / white-negative pairings.
In this talk, we will introduce and illustrate different Bayesian hierarchical modeling approaches for the IAT. First, we will attempt to characterize the typical data pattern observed in the IAT, in order to better understand the relationship between speed and accuracy. Second, based on this pattern, we will outline three analytic approaches for quantifying individual differences in implicit associations that constitute alternatives to the traditional D-score analysis of the IAT. Specifically, we apply Bayesian hierarchical multivariate regression, multinomial processing trees with response times, and lognormal race models to the IAT data.
These approaches share the benefit of integrating both response time and accuracy data and thus making use of the full resolution of the data. Additionally, the three modeling techniques have unique features that make them more or less suitable depending on the particular research question, theoretical focus, and design characteristics at hand. We will apply each model to two different datasets and discuss advantages, predictions, and individual estimates from each model.

Modular Serial-Parallel Network (MSPN): A Unified Model for Hierarchical Cognitive and Perceptual Processes

Fific, Mario
Grand Valley State University

Little, Daniel R.
The University of Melbourne

Yang, Cheng-Ta
Taipei Medical University

Session:
Symposium: Mental Architecture Model Identifiability Approaches

We will present the Modular Serial-Parallel Network (MSPN) model, a comprehensive and unified theoretical framework for cognitive and perceptual processes across various behavioral domains. MSPN has the potential to generalize to cognitive neuroscience modeling and offers a detailed mechanistic analysis of mental processes involved. In the back end, MSPN synthesizes several perceptual and cognitive approaches, including memory representations, signal detection theory, rule-based decision-making, mental architectures, random walks, and process interactivity. The MSPN model has been applied to two domains to explore the hierarchical nature of mental representations. Firstly, in face perception, MSPN proposes a hierarchical organization of visual processing with low-level features processed first, followed by higher-level features, which is consistent with the two dominant approaches in facial perception: holistic and analytic facial encoding. Also, this is consistent with the idea that mental representations of faces are organized hierarchically. Secondly, in decision-making involving preferential gamble choices, MSPN proposes a similar hierarchical organization of processing, with low-level object attributes processed first, followed by higher-level integration of these properties, which is consistent with the so-called Heuristic- and Utility based approaches to decision making. Using the joint analysis of choice response time distributions, we compared several candidate stochastic models. The MSPN has shown impressive abilities in fitting choice response time distributions over other models in tested tasks. Thus, implying that MSPN can be used as a tool for further development and refinement of theoretical constructs, with the analysis of the model's parameter values providing insights into distinct properties of perceptual and cognitive processes.

Effects of Automation Accuracy and Task Difficulty on Decision-Making Efficiency: Insights from Systems Factorial Technology

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Session:
Symposium: Mental Architecture Model Identifiability Approaches

We examined the impact of automation accuracy and task difficulty on human decision-making. We hypothesized that highly accurate aids would improve performance only under difficult conditions, and this effect would be influenced by individual selection history. Using a categorization task, we manipulated automation accuracy (high/low) and task difficulty (easy/difficult) with three types of aids presented in separate blocks or randomly intermixed to 36 participants. We used a capacity measure based on the single-target self-terminating (STST) rule within the framework of Systems Factorial Technology (SFT) to assess decision efficiency. Results showed that high-accuracy aids reduced accuracy and increased RTs compared to unaided decisions, regardless of automation accuracy and task difficulty. Notably, high-accuracy aids provided incorrect answers under difficult conditions, leading to a significant decline in performance. However, the STST capacity results showed that high-accuracy aids had supercapacity processing under difficult conditions in the block design, but not in the mixed design. These findings suggest that effective top-down control is essential to utilize high-accuracy aids to improve decision efficiency when the task is relatively difficult. Our study challenges the resource hypothesis and suggests that individuals may rely more on high-accuracy aids as task demands increase. Furthermore, these capacity differences may imply that participants utilize different decision strategies in terms of mental architecture to integrate current percept and aided information. Our research provides novel insights into the potential benefits and limitations of automated aids for information processing efficiency.

The Change of speed of retrieval of items from long-term memory: Control by the parallel hazard functions in a parallel system

Townsend, Jim
Indiana University

Session:
Symposium: Mental Architecture Model Identifiability Approaches

Classical work by Bousefield & Sedgewick in the 1940s and that by McGill in the 1960s applied what amounted to stochastic death processes with exponential interarrival times to the inter-retrieval times of times from long-term memory in free recall of items from a category. The exponential models used predicted increasingly longer inter-retrieval times over time and/or number of retrievals. We were interested in the generality of this phenomenon. Our mathematical investigations employing hazard functions, found that although this type of behavior does indeed, follow from a broad class of death processes, there exist intriguing, if perhaps unusual-in-nature, classes of hazard functions (underpinning the parallel systems) which violate this seemingly natural kind of behavior.

Selective influence and coactivity in accumulator models examined through the Grice representation

Townsend, James T.
Indiana University

Session:
Symposium: Mental Architecture Model Identifiability Approaches

Previous work has demonstrated that any joint model of choice and response time can be represented with a Grice model, that is, a race model with deterministic accumulation functions for each choice and random thresholds. Our research is on framing the space of possible choice-RT distributions in terms of their Grice model representations and particularly leveraging differential geometry to examine parametric models in that space. In this talk, we will examine the concept of selective influence through the lens of the Grice representation and highlight connections with related frameworks, particularly the coactive model.

Investigating the integration of two sources of visual information

Chen, Ying-Yu
The University of Texas at San Antonio

Houpt, Joe
University of Texas at San Antonio

Session:
Symposium: Mental Architecture Model Identifiability Approaches

Researchers suggest emergent features are fundamental to visual processing. Earlier work examined the perception of combined local information in terms of the emergent features (i.e., orientation and proximity). Our current study investigated how those emergent features combine together. To examine this question, we use change detection task. We applied systems factorial technology (SFT), a framework for measuring cognitive processes across multiple sources of information. Findings of coactive indicated people coordinate orientation and proximity together to make decisions. Results in line with parallel or serial processing indicated people process multiple sources of information simultaneously or sequentially before making decision.

Worth the Weight: Integration of Verbal and Numeric Information in Graduate Admissions

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Pleskac, Tim
University of Kansas

Biernat, Monica
University of Kansas

Girard, Jeff
University of Kansas

Session:
Assessment

In graduate admissions, as in many merit-based decisions, evaluators must judge candidates from a flood of information, including recommendation letters, personal statements, grades, and standardized test scores. Some of this information is conveyed numerically, while some is conveyed verbally. This creates a challenge for studying these decisions, as most theories of behavioral economics specifically focus on evaluating decisions using only verbal or numeric information – not both. The goal of this study is to evaluate how verbal and numeric information are used within graduate admissions decisions. We examine a uniquely comprehensive dataset of 2,231 graduate applications to the University of Kansas, containing full application packages, demographics, and final admissions decisions for each applicant. To make sense of our documents, we apply structural topic modeling, an extension of correlated topic modeling which allows topic content and prevalence to covary based on other metadata (i.e. department of study). This allows us to examine not only what information letters and statements contain, but also the effects of gender, race, and department on how that information is conveyed. We find that admissions decision committees behaved as if they prioritized numeric metrics, using verbal information to check for disqualifications if at all. Furthermore, we find that applicant race and gender influence the prevalence of topics in their letters and statements.

matriKS: An R package for rule-based automatic generation of Raven-like matrices

Epifania, Ottavia
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Brancaccio, Andrea
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Session:
Assessment

Raven-like matrices are widely used to evaluate human intelligence and abstract reasoning. However, few resources are available for automatically generating them. Some of these resources (e.g., Corvus) are hardly customizable unless one has medium-high expertise in JavaScript, while others (e.g., the IMak package in R) are mostly focused on figure analogies based on the rotation of different objects. The ideal solution would be an open-source and easy-to-use software that implements different sets of rules for the automatic generation of Raven-like matrices. This talk presents "matriKS", an R package for the automatic generation of Raven-like matrices, available on GitHub at https://github.com/OttaviaE/MatriKS. The package implements different sets of rules, from the most basic ones (i.e., visuo-spatial rules like changes in size and/or orientation) to the most complex ones (i.e., logic rules based on inferential and inductive reasoning), and allows the users to concatenate them with different directional logics (i.e., horizontal, vertical, diagonal logics). Different matrices have been generated with the matriKS package and they have been administered to a sample of Italian children (age 4-11). Validation of the matrices has been conducted via Rasch model analyses and it also considered the rules used for generating them and the different schooling levels.

Identifying cognitive skills in student data with an application in education

Taatgen, Niels
University of Groningen

Blankestijn, Jori

van Rijn, Hedderik
University of Groningen, The Netherlands

Session:
Assessment

Cognitive tutors typically use a student model to track progress of the learner. This model can be used to give feedback to teachers and students, and to select new material and assignments. Student models are typically constructed by modelers and/or education specialists. However, it is hard to assess whether the constructed student model aligns with knowledge and skills students actually need to master the material. Instead, we propose a hybrid approach, in which we use bottom-up machine learning methods to use individual differences in student performance to construct a knowledge graph, in which each node represents a possible knowledge state of the student. As a pilot, we constructed a knowledge graph for an arithmetic course in the mid-level vocational education (MBO) in the Netherlands. The basis for this graph was an math entry test, which, according to the publisher, addressed several specific topics, such as length measurements, weight, clock time, etc. However, when we constructed a knowledge graph from data from 413 students, we found that students do not differ on mastery of those topics, but rather on more general underlying skills, such as general arithmetic skills, reading skills and multi-step reasoning. A pilot conducted in two schools using a dashboard representing the knowledge graph was judged to be insightful and helpful by both teachers and students, and can serve as a basis for the construction of a cognitive tutor.

A Beta Asymmetric Unfolding Model for Continuous Bounded Responses

Noel, Yvonnick
University of Rennes 2

Session:
Assessment

Unfolding models are relevant in all cases when respondents set their agreement levels by searching some optimal level of agreement with an item: They agree to some extent, but not too much. For instance, the more we see the negative consequences of having a baby for a single mother, the more we are likely to find pros about abortion. But the more we would raise our level of agreement in favor of abortion, the more we would be concerned that lives are being stopped, and this would act as a moderator of the first concern. In this situation, responses are shaped by the particular equilibrium each respondent finds between a social concern and a natural concern for life respect. In this talk, we are interested in the general class of situations where an increase in some attitude or behavior A triggers an increase in another attitude or behavior B, that at some point, eventually becomes an inhibitor of the very process that first gave it birth. This mechanism is expressed as an explicit set of differential equations, which, upon integration, leads to a new class of potentially asymmetric unimodal response functions. The obtained solution function is integrated within a Beta Response Model (Noel & Dauvier, 2007; Noel, 2014), which properties are studied, in particular by comparison of previous proposals, and an application on a real dataset is presented and discussed.

A neural network simulation of event-related potentials in response to syntactic violations in second-language learning

Verwijmeren, Stephan

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Frank, Stefan
Centre for Language Studies, Radboud University Nijmegen, The Netherlands

Fitz, Hartmut

Khoe, Yung Han
Radboud University Nijmegen

Session:
ICCM: Neuroscience I

Event-related potentials (ERPs) are used to study how language is processed in the brain, including differences between native (L1) and second-language (L2) comprehension. In low proficiency L2 learners, syntactic violations give rise to an N400, but this changes into a P600 as their L2 proficiency increases. The precise functional interpretation of ERPs, however, remains a matter of debate. Fitz and Chang (2019) proposed a theory where ERPs reflect learning signals that arise from mismatches in predictive processing. These signals are propagated across the language system to make future predictions more accurate. We test if this theory can account for the N400-to-P600 switch in late bilinguals, by implementing a model capable of simulating the N400 and P600. We perform an experiment designed to elicit a P600 effect in simulated L2 learners progressing through learning stages. Simulated Spanish-English participants showed similar ERP effects in their L2 (English) as human participants did in ERP studies. Over the course of L2 learning, simulated N400 size decreased while P600 size increased, as it does in humans. Our findings support the viability of error propagation as an account of ERP effects, and specifically of how these can change over L2 learning.

Improving Reinforcement Learning with Biologically Motivated Continuous State Representations

Learning from experience, often formalized as Reinforcement Learning (RL), is a vital means for agents to develop successful behaviours in natural environments. However, while biological organisms are embedded in continuous spaces and continuous time, many artificial agents use RL algorithms that implicitly assume some form of discretization of the state space, which can lead to inefficient resource use and improper learning. In this paper we show that biologically motivated representations of continuous spaces form a valuable state representation for RL. We use models of grid and place cells in the Medial Entorhinal Cortex (MEC) and hippocampus, respectively, to represent continuous states in a navigation task and in the CartPole control task. Specifically, we model the hexagonal grid structures found in the brain using Hexagonal Spatial Semantic Pointers (HexSSPs), and combine this state representation with single-hidden-layer neural networks to learn action policies in an Actor-Critic (AC) framework. We demonstrate our approach provides significantly increased robustness to changes in environment parameters (travel velocity), and learns to stabilize the dynamics of the CartPole system with comparable mean performance to a deep neural network, while decreasing the terminal reward variance by more than 150x across trials. These findings at once point to the utility of leveraging biologically motivated representations for RL problems, and suggest a more general role for hexagonally-structured representations in cognition.

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Orchard, Jeff
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Stewart, Terry
National Research Council of Canada

Session:
ICCM: Neuroscience I

Novelty Detection, Insect Olfaction, Mismatch Negativity, and the Representation of Probability in the Brain

We present a unified model of how groups of neurons can represent and learn probability distributions using a biologically plausible online learning rule. We first present this in the context of insect olfaction, where we map our model onto a well-known biological circuit where a single output neuron represents whether the current stimulus is novel or not. We show that the model approximates a Bayesian inference process, providing an explanation as to why the current flowing into the output neuron is proportional to the expected probability of that stimulus. Finally, we extend this model to show that the same circuit can detect temporal patterns such as those violations of expectations that produce the EEG mismatch negativity signal.

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Session:
ICCM: Neuroscience I

Resource demands of an implementationist approach to cognition

A core inferential problem in the study of natural and artificial systems is the following: given access to a neural network, a stimulus and behaviour of interest, and a method of systematic experimentation, figure out which circuit suffices to generate the behaviour in response to the stimulus. It is often assumed that the main obstacles to this "circuit cracking" are incomplete maps (e.g., connectomes), observability and perturbability. Here we show through complexity-theoretic proofs that even if all these and many other obstacles are removed, an intrinsic and irreducible computational hardness remains. While this may seem to leave open the possibility that the researcher may in practice resort to approximation, we prove the task is inapproximable. We discuss the implications of these findings for implementationist versus functionalist debates on how to approach the study of cognitive systems.

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van Rooij, Iris
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Session:
ICCM: Neuroscience I

Single neuron distribution modelling for anomaly detection and evidence integration

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Session:
ICCM: Neuroscience I

Probability theory is often used to model animal behaviour, but the gap between high-level models and how those are realized in neural implementations often remains. In this paper we show how biologically plausible cognitive representations of continuous data, called Spatial Semantic Pointers, can be used to construct single neuron estimators of probability distributions. These representations form the basis for neural circuits that perform anomaly detection and evidence integration for decision making. We tested these circuits on simple anomaly detection and decision-making tasks. In the anomaly detection task, the circuit was asked to determine whether observed data was anomalous under a distribution implied by training data. In the decision-making task, the agent had to determine which of two distributions were most likely to be generating the observed data. In both cases we found that the neural implementations performed comparably to a non-neural Kernel Density Estimator baseline. This work distinguishes itself from prior approaches to neural probability by using neural representations of continuous states, e.g., grid cells or head direction cells. The circuits in this work provide a basis for further experimentation and for generating hypotheses about behaviour as greater biological fidelity is achieved.

Metacognitive threshold: A computational account

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West, Robert L.
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Session:
ICCM: Attention and Cognition

This paper will explore ways of computationally accounting for the metacognitive threshold - the minimum amount of stimulus needed for a mental state to be perceived - and discuss potential cognitive mechanisms by which this threshold can be influenced by metacognitive training. We apply a metacognitive skill framework to help explain how the metacognitive threshold can be lowered to allow for greater perceptual access to one's own cognitive states.

Relative attention across features predicts that common features increase geometric similarity

Seitz, Florian
University of Basel

Session:
ICCM: Attention and Cognition

The human mind relies on similarity to organize the world around it. A geometric approach to similarity, which assumes that two objects' similarity decreases with the sum of their feature value differences, has been particularly influential. Yet, geometric similarities are claimed to consider only differing features but ignore common features, which is inconsistent with human similarity judgments that get larger with additional common features (the common features effect). This paper shows that a relative attention mechanism, as it is implemented in current cognitive models based on geometric similarities, can naturally predict the common features effect by weighting each feature value difference with the share of attention allocated to the feature. Additional common features draw away attention from the already present features, which entails that the differences between objects with respect to already present features receive less weight, resulting in a higher similarity. The ability of the geometric similarity theory with relative attention to predict the common features effect is illustrated for data from Gati and Tversky (1984) and for data from a new pairwise similarity judgment experiment.

The CoFI Reader: A Continuous Flow of Information approach to modeling reading

Nicenboim, Bruno
Tilburg University

Session:
ICCM: Attention and Cognition

We present a novel cognitive model of reading based on a continuous flow of information approach, where partial information from different levels of representation is continuously being made available to next levels. In an example application, we implement the model in a hierarchical Bayesian framework and fit it to self-paced reading times data: a reading task where one word is presented at a time and the presentation time is controlled by the experimental subject. The results show that the model provides a reasonable fit to word-level reading times, and can account for two previously observed findings: (i) reading times are much shorter than the minimum time required for all cognitive processes that should take place, and (ii) the processing difficulty of a word affects the reading times of subsequent words (i.e., spillover or lag effects). Computational models have explained these findings through parafoveal preview, that is, the partial processing of upcoming words during reading before they are directly fixated by the eyes. Our model provides an explanation for these findings that is relevant for natural reading, but also, crucially, for self-paced reading, where parafoveal preview is not possible.

A Bayesian hierarchical implementation of the circular drift diffusion model

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Session:
Evidence-Accumulation Models: Methods

The circular drift diffusion model (CDDM; Smith, 2016, Psychological Review) is a sequential-sampling decision-making model used to describe the choices and response times observed in scenarios where participants have to make decisions on a circular space (i.e., the decision space is a bounded continuum that can be mapped onto a circle). Much like in Ratcliff's (1978, Psychological Review) diffusion model, a core assumption is that evidence is accumulated over time until a response threshold is reached. The parameters of the CDDM can be mapped to relevant psychological processes such as response caution and information processing speed.

We developed a custom JAGS module to facilitate working with the CDDM in a Bayesian framework. We present results from a parameter recovery study showing that the module is well suited to infer the parameter values used to generate bivariate datasets. The implementation in JAGS facilitates a number of useful model extensions: hierarchical models that capture different levels of variation across parameters (e.g., per individual, condition, experimental manipulation, etc.); latent variable models that identify their underlying factorial structure; mixture models that discern responses attributable to different simultaneously active processes; explanatory models that consider exogenous predictors; and so on.

We present an application of our CDDM JAGS module to data collected by Kvam (2019, Journal of Experimental Psychology: Human Perception and Performance) in a continuous orientation judgment task. In this study, participants were asked to indicate the mean orientation of a rapid sequence of Gabor patches shown on every trial. The task design included manipulations of boundary distance through speed vs. accuracy instructions, and manipulations of drift magnitude and drift angle variability through different difficulty conditions.

We built a hierarchical Bayesian model with a latent mixture structure to test four hypotheses: (1) The response boundary was higher when instructions prompted participants to favor accuracy rather than speed; (2) The drift magnitude decreased with task difficulty; (3) The variability in drift angle increased with task difficulty; and (4) Positive and negative deflections of the cue with respect to the true mean orientation had equivalent effects on the responses observed. We found evidence in support of all four hypotheses. We will present results and discuss further extensions of the model.

Partial derivatives and an adaptive rejection sampler for the Wiener diffusion model

Hartmann, Raphael
University of Freiburg

Meyer-Grant, Constantin
University of Freiburg

Klauer, Christoph
University of Freiburg, Germany

Session:
Evidence-Accumulation Models: Methods

The Wiener diffusion model (and its extensions in terms of trial-by-trial variability in drift rate, starting point, and non-decision time) is one of the most frequently used cognitive models for binary response tasks. A key advantage of this model framework is that it allows for jointly modeling response frequency and latency. In Hartmann and Klauer (2021) we derived the partial derivatives of th diffusion-model density with respect to up to seven model parameters as well as with respect to the response time itself. Moreover, we developed an R package (WienR) that can be used to calculate these partial derivatives (as well as the PDFs and CDFs) of the response time distribution conditional on one of the two possible responses. In Hartmann, Meyer-Grant, and Klauer (2022) we further extended the WienR package by developing and implementing an efficient adaptive rejection sampler (ARS) that builds on the above-mentioned partial derivatives. In the present talk, the partial derivatives, the ARS method, and the WienR package will be introduced.

Hierarchical Bayesian Estimation for Cognitive Models using Particle Metropolis within Gibbs (PMwG): A tutorial

Brown, Scott
University of Newcastle

Kuhne, Caroline
University of Newcastle

Stevenson, Niek
University of Amsterdam

Cooper, Gavin
University of Newcastle

Hawkins, Guy
University of Newcastle

Cavallaro, Jon-Paul
University of Newcastle, Australia

Innes, Reilly
University of Newcastle

Session:
Evidence-Accumulation Models: Methods

Estimating quantitative cognitive models from data is a staple of modern psychological science, but can be difficult and inefficient. Particle Metropolis within Gibbs (PMwG) is a robust and efficient sampling algorithm which supports model estimation in a hierarchical Bayesian framework. This talk will provide an overview of how cognitive modelling can proceed efficiently using PMwG, a new open-source package for the R language. PMwG, and the PMwG package, has the potential to move the field of psychology ahead in new and interesting directions, and to resolve questions that were once too hard to answer with previously available sampling methods.

Exploring the neurally plausible assumptions of the Ising Decision Making model

Wang, Jiashun
Ludwig Maximilian University of Munich

Donkin, Chris
LMU Munich

Session:
Evidence-Accumulation Models: Methods

The most popular models of perceptual decision making, such as the diffusion model, make relatively simple assumptions about the psychological mechanisms involved. Other models implement more plausible neural mechanisms, such as the Ising Decision Maker (IDM), which builds from the assumption that two pools of neurons with self-excitation and mutual inhibition receive perceptual input from external excitatory fields. In this study, we explore the consequences of using simple models to model more complex data with higher neural plausibility. To do this, we simulate data from the IDM and fit it with the diffusion model, looking at the relationship between the parameters that overlap in the two models. Results have shown that changes in stimulus distinctness and non-decision time in IDM corresponds exclusively to changes in drift rate and non-decision time in DDM. Though the result appears less linear, the detection box size in IDM has a selective influence on boundary separation in DDM, with smaller detection box sizes influencing boundary separation less than larger box sizes. In other simulations, we look at whether assumptions such as inhibition or evidence leakage, as they are implemented in different models, have a similar impact on predicted behavior. Similarly, results have also shown that changes in stimulus distinctness and non-decision time in IDM corresponds exclusively to changes in drift rate and non-decision time in OUM, while the negative relationship between detection box size in IDM and the boundary separation in OUM is quite noisy. In terms of the more 'complex' assumptions, we see a clear linear relationship between self-excitation in the IDM and inhibition in the OUM. This study provides preliminary evidence that the simplifying assumptions of models like the DDM do not compromise their ability to estimate their core parameters. We also found that some of the more complex assumptions also share the 'construct validity' across different models, with the leakage parameter of the OUM and self-excitation parameter of the IDM having a similar effect on predicted data.

PyBEAM: A Bayesian approach to parameter inference for a wide class of binary evidence accumulation models.

Holmes, Bill
Indiana University

Murrow, Matt
Vanderbilt

Session:
Evidence-Accumulation Models: Methods

Many decision-making theories are encoded in evidence accumulation models (EAM). These assume that noisy evidence stochastically accumulates until a set threshold is reached, triggering a decision. One of the most successful and widely used of this class is the Diffusion Decision Model (DDM). The DDM however is limited in scope and does not account for processes such as evidence leakage, changes of evidence, or time varying caution. More complex EAMs can encode a wider array of hypotheses, but are currently limited by computational challenges. In this work, we develop the python package PyBEAM (Bayesian Evidence Accumulation Models) to fill this gap. Toward this end, we develop a general probabilistic framework for predicting the choice and response time distributions for a general class of binary decision models. In addition, we have heavily computationally optimized this modeling process and integrated it with PyMC, a widely used Python package for Bayesian parameter estimation. This 1) substantially expands the class of EAM models to which Bayesian methods can be applied, 2) reduces the computational time to do so, and 3) lowers the entry fee for working with these models. Here we demonstrate the concepts behind this methodology, its application to parameter recovery for a variety of models, and apply it to a recently published data set to demonstrate its practical use.

Modelling speeded random generation as sampling for inference

Castillo, Lucas
University of Warwick

Leon Villagra, Pablo
University of Warwick

Chater, Nick
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Sanborn, Adam
University of Warwick

Session:
Probability and Randomness Judgement

In a random generation task, participants are asked to randomly generate a sequence of items (e.g., from numbers 1-10). Past work conclusively established that human random generation is flawed, and participants' sequences become less random the faster they are asked to produce them (Towse, 1998). These results have been interpreted as the result of items being generated according to simple schemas (e.g., add one or subtract one) with effortful inhibition of typical outputs, and so faster sequences lead to more stereotyped behaviour (Jahanshahi et al., 2006).

However, we have recently reinterpreted random generation as drawing samples for inference: people's internal sampling process resembles algorithms used in computer science, such as Markov Chain Monte Carlo (Castillo et al., 2023). One empirically-verified prediction of this approach is that participants can randomly generate examples from non-uniform distributions, such as the distribution of UK heights.

If that is the case, then what are the causes for people's more stereotyped random generation under speeded conditions? Is it that at higher production speeds people generate fewer samples between utterances, leading to differences in the resulting sequences? Or does the sampling process change qualitatively when a speed threshold is reached, either in terms of parameters or even structure?

We asked participants to randomly produce UK lifespans both at 40 and 80 items per minute, and compared the sequences they produced to several computational models. We assessed how well characteristic features of the sampling algorithm that have been informative in previous experiments changed under speeded conditions. We found large individual differences (which previous research focusing on average trends has not identified), with some participants being more random in the faster sequence, contrary to previous findings. Our results provide insight into the noise and individual variability in cognition, and will help develop better computational models of human inference and decision-making.

How do people predict a random walk? Lessons for models of human cognition

Spicer, Jake
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Chater, Nick
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Sanborn, Adam
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Session:
Probability and Randomness Judgement

Repeated forecasts of changing targets are a key aspect of many everyday tasks, from predicting the weather to financial markets. A particularly simple and informative instance of such moving targets are random walks: sequences of values in which each point is a random movement from only its preceding value, unaffected by any previous points. Moreover, random walks often yield basic rational forecasting solutions in which predictions of new values should repeat the most recent value, and hence replicate the properties of the original series. In previous experiments, however, we have found that human forecasters do not adhere to this standard, showing systematic deviations from the properties of a random walk such as excessive volatility and extreme movements between subsequent predictions. We suggest that such deviations reflect general statistical signatures of human cognition displayed across multiple tasks, offering a window into underlying cognitive mechanisms. Using these deviations as new criteria, we here explore several cognitive models of forecasting drawn from various approaches developed in the existing literature, including Bayesian, error-based learning, autoregressive and sampling mechanisms. These models are contrasted with human data from two experiments to determine which best accounts for the particular statistical features displayed by participants. We find support for sampling models in both aggregate and individual fits, suggesting that these variations are attributable to the use of inherently stochastic prediction systems. We thus argue that variability in predictions is primarily driven by computational noise within the decision making process, rather than "late" noise at the output stage.

Investigating the symmetry of human probability judgment biases

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Session:
Probability and Randomness Judgement

People's probability judgments are both biased and variable. When asked to judge the probability of binary events, e.g., whether it will rain or not, there is a bias away from extreme values. In addition, there is substantial variability when judgments of the same question are repeated, even when no new information has been presented. This combination of bias and variability has been best explained by sampling-based models. Variability is neatly explained by people basing their probability judgments on randomly recalled or simulated events. Bias though is not an inherent property of random samples, so bias is introduced through noisy counting of samples (e.g., Probability Theory Plus Noise; Costello & Watts, 2014) or by application of a generic prior over probabilities themselves to improve judgment accuracy for small numbers of samples (e.g., Bayesian Sampler; Zhu, Sanborn, & Chater, 2020). These two mechanisms make equivalent predictions for average judgments but are distinguished by their predictions for the relationship between the judgment mean and variance. Using, a recent regression-based technique, Sundh, Zhu, Chater, and Sanborn (in press) found empirical evidence for a generic prior. But the flexibility of the prior was not tested – can it adapt, particularly to environments in which probabilities are not symmetrically distributed (e.g., there are more small, or large, probabilities).? Here we expand the regression-based technique to allow it to identify either symmetric or asymmetric generic priors. Applied to four previous experiments in which participants make repeated probability judgments, the recovered generic prior was close to symmetric. These previous experiments however asked participants to judge event distributions that were themselves symmetric, so to provide a better test, we ran two new experiments in which the distribution of probabilities to judge were asymmetric. We again found that the prior was close to symmetric, suggesting that perhaps the mind has symmetry constraints, the generic prior reflects long-term experience, or that the generic prior is not represented at all but implemented "procedurally" by fixed a process of regression to the mean.

Measuring polarization of risk perceptions

Fischer, Olivia
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Frey, Renato
University of Zurich

Session:
Probability and Randomness Judgement

3. Results:
Regarding our first research question, we found that six out of the twelve unique combinations indicate credible polarization based on our pre-defined region of practical equivalence (ROPE) for the bimodality coefficient. Specifically, we found four cases of credible polarization in the finance condition and two in the health condition. In the finance condition, it was the mandatory certificate, lockdown, and vaccine mandate for one's financial situation and the vaccine mandate for others' financial situation that were polarized. In the health condition, it was the mandatory certificate and vaccine mandate for one's own health situation that were polarized. It is also notable that the other distributions are relatively uniformly distributed, indicating a high degree of variation and lack of agreement even in the non-polarized distributions of participants' risk perceptions.
Regarding our second research question, we compared the posterior estimate of the bimodality coefficient to seven other operationalizations of polarization and found that there is relatively strong agreement between measures. The average absolute correlation (i.e., disregarding the sign) between measures is 0.58.
4. Conclusions & Significance of research:
In conclusion, our results suggest that there is credible polarization in regards to certain Covid-19 measures, specifically those that have personal consequences. Moreover, we find that different measures of polarization tend to agree, at least regarding the relatively uniformly distributed data that we observed.
Our research highlights the importance of considering the context in which polarization is measured and how it is conceptualized. Furthermore, these findings have important implications for public policy: They suggest that interventions aimed at reducing polarization should focus on addressing risks that individuals may perceive for themselves. In a second study, we use precisely these insights to implement an intervention based on one-on-one interactions between individuals with differing risk perceptions.

Get'cha Head in the Game: Testing Context Effects for Naturalistic Stimuli in Basketball

Fang, Jun
University of Kansas

Cai, Xiaohong
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Adaryukov, James
University of Kansas

Pleskac, Tim
University of Kansas

Session:
Probability and Randomness Judgement

Leading theories of subjective probability judgments (SPs) model SPs in terms of the support, or strength of evidence, assigned to a focal hypothesis relative to the support of alternative hypotheses. These theories assume that each hypothesis elicits a fixed level of support regardless of the other hypotheses under consideration. Contradicting this idea, recent research on SPs has found context effects – changes in support for one hypothesis based on the other hypotheses under consideration (Cai & Pleskac, 2023). However, these results were obtained using artificial stimuli in laboratory settings. Do context effects in belief occur in naturalistic forecasting environments? To investigate this, we conducted a study where $N = 113$ participants judged the likelihood of the final ranking of the men's NCAA basketball teams one month out. The study occurred in two phases. First, participants were asked to map 50 basketball teams onto a two-dimensional space using a Spatial Arrangement method. Then, based on their mental representations, we presented customized triplets of teams designed to elicit context effects in each participant and asked them, across 180 trials, to judge the probability of one team ranking higher than the other two in the NCAA's final rankings. Our findings suggest that similarity and attraction effects can occur in this naturalistic environment, and there is some evidence of a compromise effect. These results invalidate the support invariance principle, which rules out a large class of psychological theories of subjective probability judgments that assume this principle. Furthermore, they suggest that belief and preference construction may be driven by similar processes.

A runnable neural network model of the structure and dynamics of human personality embedded in a virtual environment

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The Ohio State University

Read, Stephen
University of Southern California

Session:
Social Cognition

We present a single-agent neural network model, based on the biologically plausible neural network framework Emergent (O'Reilly et al., 2020), that operationalizes our theory of how individual differences in the neural systems underlying motivation interact with situational characteristics to give rise to within-subject personality dynamics (Read et al., 2010). We first manipulate key parameters of our neural network model to create "individuals" varying in their underlying motivational structure and dynamics. We then simulate the interaction of these individuals with varying situational configurations in virtual environments created with the video game engine Unity to provide a complex model explaining multifarious factors including: A) how situational configurations produce high within-subject variability in behavior; B) how certain situational configurations give rise to some personality factors more than others; C) the degree to which one's personality structure as opposed to one's environment plays a role in producing behaviors; and D) how physiological factors influence the presentation of the Big Five personality factors through behaviors.

Cognitive Modeling of Attitude Change Process Through Persuasion

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The University of Tokyo

Okada, Kensuke
University of Tokyo

Session:
Social Cognition

Social psychology has not yet examined the attitude change process in a situation where someone is persuaded in multiple directions from different sources. To examine the process in such a situation, Nakamura and Miura (2019) conducted an experiment that manipulated the cognitive resources of the participants and showed the applicability of the heuristic-systematic model (HSM), which is known as a model of the attitude change process in unidirectional situations.
In this study, we propose a cognitive model that can not only tests the applicability of the HSM in such a situation but also quantifies the quality of the stimuli and manipulations used in the experiment from the data. In addition, we fitted the data from Nakamura and Miura's study (2019) to the cognitive model and estimated the parameters in a Bayesian way. As a result of the posterior predictive check and the model comparison by the Bayes factor, it was shown that the HSM is applicable in such a situation; however, some evidence against the HSM was also obtained from the posterior predictive check. Moreover, parameter estimates indicated that the quality of some stimuli and manipulations was not as intended by the experimenter.

The wisdom of the crowd when people choose what they rank

Lee, Michael
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Montgomery, Lauren
University of California, Irvine

Session:
Social Cognition

The wisdom of the crowd effect is the finding where a group aggregation of the crowd is more accurate on average than any random individual from the crowd. The wisdom of the crowd can be applied to a variety of tasks, such as a ranking one where participants are told to rank a set of items according to some criterion. In past work that applies the wisdom of the crowd to ranking tasks, participants are typically asked to rank all items (Lee et al., 2014) although they have also been asked to rank a random subset of the items (Lee et al., 2022). We consider how aggregated rankings are affected when participants are allowed to choose which items they include in their ranking and which items they exclude. Previous work on binary-choice trivia questions found that wisdom of the crowd aggregates were more accurate when individual participants chose which questions they wanted to answer (Bennett et al., 2018). We develop a Thurstonian model for our novel subset ranking task and evaluate performance by comparing the model-generated ranking to the correct ranking.
References:
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Cascading transitions in psych-social systems

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Session:
Social Cognition

Tipping points or phase transitions separate stable states in psycho-social systems. Examples are quitting smoking, radicalization, and dropping-out of school. Two knowledge gaps prevent our ability to predict and control these tipping points. First, we miss explanatory mathematical models of such non-linear processes. Second, we ignore the multilevel character of psycho-social transitions.
I contend that important changes in many psycho-social systems are cascading transitions, where individual transitions trigger or are triggered by social transitions. The cascade of radicalization of individuals in the context of political polarization in societies is an example of such a multilevel process.
In this talk I will present and discuss a mathematical approach to the study of cascading transitions.
This approach comprises theory construction in the form of mathematical modelling and innovative empirical analyses. The basic cascading transition model is:
$dX_i/dt = -X_i^3 + a_i + \sum_j b_{ij} X_j + \sum_j c_{ij} X_i X_j$
With specific choices of a, b and c we can apply this model in different contexts. Variants of this complicated model have been recently analysed in climate research (Dekker et al., 2018; Klose et al., 2020; von der Heydt et al., 2019), mostly for the case that $c_i j = 0$.
In a new ERC project, we will apply this model to: a) opinion change from individuals to populations and back, b) learning, where progression and drop-out are embedded in collective processes, c) addiction, where transitions to addiction or abstinence within individuals are part of cascading epidemiological changes of substance use in populations, d) muti-figure multistable perception. These individual projects will also be presented as posters.

Bayesian graphical modeling in network psychometrics

marsman, Maarten
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Session:
Symposium: Bayesian Graphical Modeling in Psychology

Network psychometrics uses undirected graphical models to model the network structure of complex psychosocial systems. This talk will introduce Bayesian graphical modeling, the Bayesian approach to the analysis of psychological networks and the topic of this symposium. Estimating the causal structure of a psychosocial system from correlational data is extremely difficult, so the field has focused instead on estimating the conditional independence and dependence structure. In this context, Markov Random Field (MRF) models are an important class of undirected graphical models because their parameters provide direct information about the conditional independence structure of the underlying system. We discuss new and old MRF models for psychological variables, especially binary and ordinal variables, and the computational and conceptual challenges in their Bayesian analysis. The ultimate goal of these analyses is the Bayes factor test of conditional independence, and we discuss how this significantly advances the field of network psychometrics.

Evaluation of Network Models for Ordinal Data

haslbeck, jonas haslbeck
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Session:
Symposium: Bayesian Graphical Modeling in Psychology

Network models have become a popular tool for studying multivariate dependencies in psychological data. The most popular models are the Ising model for binary data and the Gaussian Graphical Model (GGM) for continuous data. However, most cross-sectional data are in fact ordinal. For example, personality questionnaires are scored on Likert scales, symptoms are rated in ordered categories of severity, and opinions and attitudes are measured on scales ranging from strong disagreement to strong agreement. Recently, however, appropriate network models for ordinal data have been developed that eliminate the need to binarize the data or model ordinal variables as continuous. In this paper, we discuss existing network models for ordinal data that either use a latent continuous distribution or model ordinal variables as manifest variables. We then provide a large-scale simulation study that evaluates the absolute and relative performance of these ordinal network models and contrasts them with the misspecified GGM. Based on these results, we discuss the advantages and disadvantages of each method and provide guidance as to when each method is most appropriate.

An overview of parameter estimation methods in the Ising model

Keetelaar, Sara
University of Amsterdam

Session:
Symposium: Bayesian Graphical Modeling in Psychology

In recent years, graphical models have gained interest in psychology for modelling relationships between variables. On of the most popular models is the Ising model for binary data. The model contains parameters for the main effects of the variables as well as interaction parameters between the variables. Estimating these parameters is challenging due to the intractable normalising constant in the probability density function. For this reason, the straightforward method of maximum likelihood estimation can only be used for small networks (up to 15 nodes). For larger networks, approximate methods are used, in particular the joint pseudo-likelihood method is often used. This method is known to be consistent. However, for finite samples, not much is known about how well it estimates parameters. In addition to this method, other approximate likelihood methods are often used for parameter estimation, such as the independent conditional likelihood method, which evaluates the conditional likelihood of each variable given the rest of the variables separately, or methods that try to simplify the normalizing constant, which we call the observed population method. In this talk, an overview of all these parameter estimation methods is provided. First theoretically, discussing the advantages and shortcomings of each method. Secondly, a simulation study will provide insights into how the methods actually perform against each other under different circumstances, such as varying network structures and different graph and sample sizes.

Hierarchical Gaussian graphical models and group level networks

van den Berg, Don
University of Amsterdam

Session:
Symposium: Bayesian Graphical Modeling in Psychology

The Gaussian graphical model (GGM) is often used to estimate the network structure of high-dimensional data. However, the standard Gaussian graphical model does not describe hierarchical structures in the data, which frequently occur in empirical research. For example, in fMRI studies, each participant has an individual network, but participants are also related as they form a population. Nevertheless, a common approach to analyze such data is to fit a GGM for each participant individually, thereby neglecting the shared variance. This talk discusses an extension of the GGM that describes hierarchical data. We relate the networks of individuals using Markov random field priors on the edge structure. Specifically, we use the Ising model and the Curie-Weiss model as Markov random field priors. This approach simultaneously captures the shared variance between the graph structure of different individuals and estimates a group-level network. The method is illustrated with an application on resting state fMRI data.

Three approaches for conditional independence testing: An introduction and application within psychopathology research

Huth, Karoline
University of Amsterdam

Session:
Symposium: Bayesian Graphical Modeling in Psychology

In network psychometrics, constructs are oftentimes argued to map onto causal structures. Researchers have developed the graphical approach to causal inference as a formal framework in which causal relationships are represented as directed acyclic graphs (DAGs). It is difficult to model the directed, causal structures from correlational data; conditional dependencies and independencies are key to identifying DAGs that are consistent with observed data. The Bayesian approach provides three main methods that can test for conditional independence within graphical models: the credible interval, the Bayes factor, and the Bayesian model-averaged inclusion Bayes factor. In this talk, we will provide an introduction to these three approaches, highlight their strengths and limitations, and discuss a small-scale simulation study comparing the performance of these methods. Using the Bayesian model-averaging approach, we introduce the edge evidence plot for network psychometrics. The edge evidence plot visualizes the conditional (in)dependence relationship between variables. Its use will be illustrated with an example in the field of psychopathology. As such, in this last talk of the symposium, we aim to highlight the benefits of adopting the Bayesian approach to network analysis for applied researchers.

Optimal and human performance buying airline tickets

Lee, Michael
University of California, Irvine

Chong, Sara
University of California, Irvine

Session:
Thinking and Reasoning

Buying an airline ticket is a familiar optimal stopping problem. The goal is to minimize the cost of the ticket, but this is made difficult by changes in the price over time. Part of the change in ticket prices is unpredictable fluctuation, but part is a predictable change in the price distribution, which notoriously increases rapidly as the day of travel approaches. Managing this uncertainty is the key to good decisions, since if a cheap ticket is not purchased it is not possible to go back in time, but once a ticket is purchased future prices are not available. We study how people solve this problem in a controlled experiment, using changing price distributions based on airline industry analysis. Over a set of problems, people are given 12 opportunities to buy a ticket ranging from 6 months before travel to 1 day before. We characterize their behavior in terms of threshold models, and compare their performance to optimal purchasing behavior.

An integrated choice and latent variable decision field theory model linking preferential choice responses and thinking patterns.

Hancock, Thomas
University of Leeds

Song, Fangqing
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Hess, Stephane
University of Leeds

Mushtaq, Faisal
University of Leeds

Session:
Thinking and Reasoning

Thus far, models for large-scale multi-attribute, multi-alternative preferential choice data typically include sociodemographic parameters to capture deterministic heterogeneity in preferences and use random parameters or latent class constructs to capture stochastic heterogeneity. Integrated choice and latent variable (ICLV) models are also often used to explain both attitudinal responses and preferential choice. Recently, several ideas from psychology have been incorporated into large-scale choice modelling including the use of psychological choice models (decision field theory) for travel route and mode choice behaviour. However, thus far, neither econometric or psychological choice models have incorporated or modelled different possible thinking styles (e.g. 'actively open-minded' vs 'closed-minded'; 'intuitive thinker' vs 'effortful thinker') that may vary more substantially across individuals from different parts of the world. We collect attitudinal data, responses to questions on thinking style, and choice responses to stated preference tasks on travel mode from 1,100 respondents from the East (China, Singapore), Middle East (UAE) and the West (Sweden, UK, USA). In particular, we use the data to develop an integrated choice and latent variable decision field theory model that disentangles the effects of socio-demographic characteristics, attitudes towards the environment/technology adoption and thinking styles on the travel choices. The results reveal that there are significant differences in environmental awareness, technology adoption and thinking styles among the respondents. In particular, an individual's geographical location has a larger impact on their choices, attitudes and thinking styles than sociodemographic variables such as age, gender and income.

A Simple Model for Mixing Intuition and Analysis

Katsikopoulos, Konstantinos
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Egozcue, Martin

Fuentes Garcia , Luis

Session:
Thinking and Reasoning

Firefighters, emergency paramedics, and airplane pilots are able to make correct judgments and choices in challenging situations of scarce information and time pressure. Experts often attribute such successes to intuition and report that they avoid analysis. Similarly, laypeople can effortlessly perform tasks that confuse machine algorithms. We utilise research on human intuitive decision making to build a model of mixing intuition and analysis over a set of interrelated tasks, where the choice of intuition or analysis in one task affects the choice in other tasks. In this model, people may use any analytical method, such as multi-attribute utility, or a single-cue heuristic, such as availability or recognition. We make two contributions. First, we study the model and derive a necessary and sufficient condition for the optimality of using a positive proportion of intuition (i.e., for some tasks): Intuition is more frequently accurate than analysis to a larger extent than analysis is more frequently accurate than guessing. Second, we apply the model to synthetic data and also natural data from a forecasting competition for a Wimbledon tennis tournament and a King's Fund study on how patients choose a London hospital: The optimal proportion of intuition is estimated to range from 25% to 53%. The accuracy benefit of using the optimal mix over analysis alone is estimated between 3% and 27%. Such improvements would be impactful over large numbers of choices as in public health.

Informing ethical decisions of autonomous vehicles through video-based choice experiments and brain recordings.

Maksimenko, Vladimir

National University of Singapore

Kim, Eui-Jin
Ajou University

Bansal, Prateek
National University of Singapore

Session:
Thinking and Reasoning

Autonomous vehicles (AVs) are no longer fictional. The success of AVs will depend on how they handle ethical issues in a socially acceptable manner. For example, the decisions that AV should make when there is no way to save everyone (i.e., the trolley problem). A famous cross-cultural Moral Machine experiment evaluated societal expectations about the ethical principles that should guide AV behavior in scenarios based on the trolley problem paradigm and showed that the subjective beliefs of the population play a critical role in the valuation of the ethical aspects of AV behavior. This study aims to expand our knowledge related to the effect of subjective beliefs on the valuation of the ethical aspects of AV behavior. We hypothesize that the brain activity of respondents may provide additional information about the subjective aspects of the valuation process. To test the hypothesis, we carry out video-based discrete choice experiments in which participants choose between two victims/pedestrians of road accidents involving an AV. The experiment is designed such that the AV has no choice but to hit one of two pedestrians approaching from both ends of the road. We vary the socio-demographics, such as the age and gender of the pedestrians, across trials to reveal their impact on the participant's decisions. We fit a discrete choice model (DCM) to experimental data to uncover the impacts of the considered socio-demographics on choices. Finally, we test if the different neural mechanisms (biomarkers) could explain the valuation of socio-demographics and incorporate them into DCM to better account for the subjective beliefs of the respondents.
Our study contributes to multiple fields, including AV research, choice modeling, and psychology. For AV research, we enhance our understanding of societal expectations about ethical aspects of AV behavior. For choice modeling, we advance traditional choice models by including brain signals. For psychology, we reveal mechanisms underlying the perception and valuation of ethical problems.

What do people mean by "If there is not beer then there is wine"?

Lee, Michael
University of California, Irvine

Cruz, Nicole
Innsbruck University

Session:
Thinking and Reasoning

A central question in reasoning research is what computational level principles, if any, people follow when drawing inferences and when making judgments about how strong or weak a particular inference is. Any measure of inference quality depends on the meaning people ascribe to the statements that make up the inference. The statement types with the most contentiously debated meaning in the literature are conditionals. For example, whether the inference "There is beer or wine. Therefore if there is not beer then there is wine" is deductive or not depends on how the conditional that makes up its conclusion is interpreted. Distinguishing between different interpretations of conditionals requires finding situations in which they lead to non-overlapping behavioral predictions. We present a Bayesian latent-mixture model to distinguish between a material conditional, a probabilistic conditional, and a probabilistic biconditional interpretation of conditionals along with a fourth response to capture guessing. The model correctly classifies the responses expected under each interpretation given premise and conclusion probability judgments for six inference types. We simulate data to illustrate the behavior of the model and discuss characteristics of experiments that would be required to distinguish between interpretations.

An integrative model of human response processes in Raven's Matrices

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Université du Québec à Montréal

Sun, Ron
Rensselaer Polytechnic Institute

Dai, David
State University of New York at Albany

Session:
ICCM: Cognitive Architectures

This paper presents Xyrast, an integrative model of human response processes on the Raven's Matrices family of fluid intelligence tests, and reports on a simulation study addressing its response characteristics and verisimilitude. Xyrast is implemented in the Clarion cognitive architecture and models the influence of response strategy, working memory capacity, and persistence on performance. Simulations suggest that the model captures a wide range of phenomena offering, in some cases, novel explanations for observed results. These findings suggest several avenues for future research.

From knowledge graph to cognitive model: a method for identifying task skills

Akrum, Ivana
TNO

Taatgen, Niels
University of Groningen

Session:
ICCM: Cognitive Architectures

When we learn new tasks, rather than starting from scratch, we often reuse skills that we have learned previously. By integrating these previously learned skills in a new way, we can learn how to do new tasks with little effort. In this research, we test a method aimed at identifying the skills reused between tasks. More specifically, we use a knowledge graph as a tool for identifying reused skills. From this knowledge graph, we built a cognitive model that shows how the identified skills can be integrated to solve a new task. The final cognitive model can successfully solve a variety of related but distinct tasks. This shows it is possible to use knowledge graphs to identify the skills reused between tasks. This ability may benefit how we approach learning. Knowing, in advance, the skills needed to successfully complete a new task may allow us to learn said task in an easier, more focused manner.

Using neural networks to create fast and reusable approximate likelihood functions for ACT-R

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Parallax Advanced Research

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Air Force Research Laboratory

Stevens, Christopher Adam
Air Force Research Laboratory

Session:
ICCM: Cognitive Architectures

Likelihood functions form the basis for statistical inference techniques, including maximum likelihood estimation, and Bayesian estimation/model comparison. Unfortunately, deriving likelihood functions analytically for cognitive architectures such as ACT-R can be challenging, if not impossible in some cases, often requiring considerable time and expertise. Simulation-based approximations are computationally intensive, making them impractical to implement in real-time applications. We demonstrate how recently developed techniques for learning intractable likelihood functions with neural networks can be applied to a visual search model based on ACT-R, and reused once trained. Our work extends prior applications in two ways: (1) we demonstrate that the technique can be scaled to a large number of conditions based on the size of the visual search array, and (2) we demonstrate that the technique is applicable to both unimodal and multimodal versions of the model. We conclude with a discussion for scaling up neural network techniques for approximating likelihood functions.

Cognitive Models for Human Error Generation and Detection

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Bagherzadehkhorasani, Amirreza
Penn State University

Session:
Bias, Beliefs, and Errors

Human errors can have significant consequences in various domains, such as healthcare, transportation, and finance. The ability to identify and mitigate human errors is critical for ensuring the safety and well-being of individuals and organizations. Cognitive models have the potential to inform the designers of systems about the potential for errors. Replacing users with models that simulate users' behaviors has been a long-standing vision in interface design. Cognitive models can simulate users' cognitive processes and behaviors, but they cannot fully interact with user interfaces and simulate all types of behaviors. These models currently do not have the ability to detect and mitigate human errors, and there is still much progress to be made in incorporating error handling.

This work proposed two possible approaches to address the generation and detection of human errors in cognitive models: Deterministic Error Cognitive Model and Automatic Error Cognitive Model. We model user errors in Microsoft Excel. Excel is a widely used software application that plays an important role in various industries, such as data analysis. Users make errors while working with Excel spreadsheets, which can lead to financial losses, errors in data analysis, and other negative outcomes.

We utilized existing data from a behavioral study that involved 23 participants performing a spreadsheet task in Excel. We focus on the errors that arise from the participants typing. Understanding the cognitive processes that contribute to user typing errors in Excel can help improve the software's design, training programs for users, and error detection methods. Studying user errors in a task can also identify common mistakes made by users while completing the task and develop strategies to prevent or mitigate them. Additionally, understanding sub-tasks with higher user errors can help us design better task instructions that can reduce the cognitive load on users and reduce the likelihood of errors. The performance of models is compared with human data, and while both models show a high correlation, the Automatic Error Cognitive Model predicts user behavior with a lower error rate. Furthermore, both models operate on the same interface that users interact with, utilizing a vision and motor extension tool called VisiTor (Vision + Motor).

Improving machine learning model calibration using probabilistic labels obtained via wisdom of the crowd

Epping, Gunnar
Indiana University Bloomington

Trueblood, Jennifer
Indiana University Bloomington

Holmes, Bill
Indiana University

Martin, Daniel

Caplin, Andrew

Session:
Bias, Beliefs, and Errors

An accurately labeled dataset is required to train a neural network on a classification task successfully. These labels are typically deterministic, corresponding to some ground truth. During training, a neural network learns an input-output mapping that maximizes the probability of the ground truth label for each stimulus. But what about tasks where ground truth is difficult to obtain? We introduce the use of incentive-compatible belief elicitation for labeling data and training machine learning models. Extending the work of Hasan et al. (2023), we harness the wisdom of the crowd through elicited beliefs, and then evaluate these methods in an experiment in which participants stated their belief that a white blood cell was cancerous for a series of cell images. We then trained different neural networks to classify the white blood cell images, where some networks were trained using deterministically labeled images and others were trained using the probabilistically labeled dataset obtained through elicited beliefs, and compared classification accuracy and calibration across the networks.

Measuring processing biases in balanced argument experiments

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Shamon, Hawal
Forschungszentrum Jülich

Session:
Bias, Beliefs, and Errors

How do people revise their opinions when exposed to a balanced and diverse information diet? By combining a balanced-argument experiment with a computational theory of argument communication we shed new light on this question.
Empirical studies repeatedly examined whether or not biased processing of balanced arguments may lead to more extreme attitudes and contribute to polarization tendencies, but empirical evidence remains mixed. Two forces counteract one another in such a balanced-argument setting: first, there is a moderating effect of being exposed to arguments from both sides. Second, there is a polarizing effect of filtering the information mix in favor of existing beliefs (biased processing). Our theoretical model takes into account that biased processing may come in degrees. Drawing on the theory we develop an artificial experiment — a computational miniature of the real one — and analytically derive a response function for the expected attitude changes. This function contains the strength of biased processing (β) as a free parameter. Theoretical analysis reveals a sharp transition from attitude moderation to polarization indicating that small, domain-specific variations in the strength of biased processing may result in qualitatively different patterns of attitude change, both consistent with our theory.
In the empirical experiment ($N = 1078$) individuals are exposed to an equal share of 7 pro and 7 counter arguments regarding 6 different technologies for energy production (for each N > 170). Attitudes are measured before and after exposure. Using this data we estimate the strength of biased processing for the six empirical topics. While the processing bias is in the regime of attitude moderation for gas and biomass, it is significantly higher and in the regime of polarization for coal, wind (onshore and offshore) as well as solar power.
If time permits, we will discuss the implications of these results for group deliberation processes.

The Causal Effect of Anxiety on Jumping-to-Conclusion Bias

Using the classic beads task, some research indicates that individuals with high anxiety possibly make hasty decisions based on less information (i.e., jump to conclusions) relative to healthy participants. However, the mechanisms underlying this psychopathology-related reasoning bias are not well understood. The present study investigated the causal effect of state anxiety on the jumping-to-conclusion bias and explored the underlying reasoning mechanics using the Bayesian computational modelling method, specifically focusing on the assignment of evidence weights. Approximately 50 participants were recruited from a university setting. The participants were randomly allocated to an anxiety induction condition whereby participants were instructed that they were to deliver a speech that would be evaluated, or to the control condition in which there was no speech task. Participants also completed two variants of the Beads Task: the classic version and a social variant focusing on the accumulation of social evaluative information to support decision making. The preliminary results suggested no significant differences in the number of beads sampled across experimental conditions. However, there were significant differences across experimental conditions in terms of how participants assigned evidence weights to the information sampled. Participants in the anxiety condition exhibited a more cautious and slower belief updating pattern by allocating significantly heavier weights to less frequently occurring information compared to those in the control condition. This pattern of results was observed in both classic and social Beads Tasks. Importantly, the preliminary findings imply that anxiety promotes cautiousness in belief revision instead of jumping-to-conclusion bias per se.

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Session:
Bias, Beliefs, and Errors

Towards Theory Integration: Connecting Hindsight Bias and Seeding Effects

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Session:
Bias, Beliefs, and Errors

When people estimate the quantities of objects (e.g., country populations), are then presented with the objects' actual quantities, and subsequently asked to remember their initial estimates, responses are often distorted towards the actual quantities. This hindsight bias—traditionally considered to reflect a cognitive error—has more recently been proposed to result from adaptive knowledge updating. But how to conceptualize such knowledge-updating processes and their potentially beneficial consequences? Here we provide a methodological and analytical framework that conceptualizes knowledge updating in the context of hindsight bias in real-world estimation by formally connecting it with research on seeding effects—improvements in people's estimation accuracy after exposure to numerical facts. This integrative perspective highlights a previously neglected facet of knowledge updating, namely, recalibration of metric domain knowledge, which can be expected to lead to transfer learning and thus improve estimation for objects from a domain more generally. We develop an experimental paradigm to investigate the association of hindsight bias with improved estimation accuracy. This paradigm allows for the joint measurement of both phenomena with the same formal approach. In Experiment 1, we demonstrate that the classical approach to triggering hindsight bias indeed produces transfer learning. In Experiment 2, we provide evidence for the novel prediction that hindsight bias can be triggered via transfer learning; this establishes a direct link from knowledge updating to hindsight bias. Our work integrates two prominent but previously unconnected research programs on the effects of knowledge updating in real-world estimation and supports the notion that hindsight bias is driven by adaptive learning processes.

Procedures for constructing minimal, yet maximally informative tests for skill assessment

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Session:
Knowledge Spaces

Competence-based knowledge space theory and cognitive diagnostic models are two theoretical frameworks that allow for assessing the latent set of skills an individual has available (here referred to as the "skill profile") from the observed responses to test items. Competence-based test development (CbTD) is a recent and novel approach for constructing, improving, and shortening tests for skills assessment, that may be of interest to practitioners in the two aforementioned frameworks. CbTD exploits concepts originally introduced in rough set theory to construct tests that are as informative as possible about individuals' skill profiles (i.e., adding any item does not make the tests more informative) and minimal (i.e., no item can be eliminated without making the tests less informative). Let a competency be a set of skills such that an item requiring them is available or can be constructed. A fundamental concept that underlies the construction of the tests is that of a reduct, which is defined as a minimal collection of competencies that is as informative about the skill profiles as a larger set. The talk presents two procedures for constructing a reduct. One is a competency deletion procedure that starts with a full set of competencies and consecutively deletes one competency at a time until a reduct is obtained. The other is a competency addition procedure that starts with the empty set of competencies and consecutively adds one competency at a time until a reduct is obtained. Exemplary applications of the two procedures to test construction are presented and discussed.

Toward a unified perspective on assessment models, a perspective on KST, CDA, and IRT

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Session:
Knowledge Spaces

In the past years, several theories for assessment have been developed within the overlapping fields of Psychometrics and Mathematical Psychology. The most notable are Item Response Theory (IRT), Cognitive Diagnostic Assessment (CDA), and Knowledge Structure Theory (KST). In spite of their common goals, these frameworks have been developed largely independently, focusing on slightly different aspects. Yet various connections between them can be found in literature (see, e.g., Junker & Sijtsma, 2001; von Davier, 2005; Stefanutti, 2006; Di Bello, Roussos, & Stout, 2007; Ünlü, 2007; Hong et al., 2015; Heller et al., 2015; Noventa et al., 2019, to name only a few). A unified perspective is suggested that uses two primitives (structure and process) and two operations (factorization and reparametrization) to derive IRT, CDA, and KST models. A Taxonomy of models is built using a two-processes sequential approach that captures the similarities between the conditional error parameters featured in these models and separates them into a first process modeling the effects of individual ability on item mastering, and a second process representing the effects of pure chance on item solving.

Modeling symmetries in human problem solving and problem space homomorphisms

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Session:
Knowledge Spaces

In procedural knowledge space theory (PKST), the family of solutions for a given problem is called a "problem space". The knowledge of a problem solver is represented as a specific subset of a problem space that satisfies the "sub-path assumption". Different types of "symmetries" could be found in a problem space that make certain parts of it "equivalent". These equivalence relations are introduced here as a homomorphism of one problem space into another problem space. Two types of homomorphisms are examined, which are named the "strong" and the "weak homomorphism". The former corresponds to the usual notion of "operation preserving mapping". The latter preserves operations in only one direction. The practical application of the proposed approach is presented through an empirical application with the Tower of London (TOL) test. A problem of the TOL consists of matching an initial configuration (i.e., a spatial disposition of colored balls on the pegs) with a goal configuration using the minimum number of moves. Due to the physical features of the TOL, several "symmetries" can be hypothesized. The introduction of symmetries leads to the construction of a problem space that is homomorphic to the original one. In particular, the homomorphic problem space is usually simpler and more abstract than the original one. Different symmetries hypothesis lead to different problem spaces which were empirically validated and compared with one another. The results of the empirical study are presented and discussed.

On the identifiability of the Polytomous Local Independence Model (PoLIM)

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Session:
Knowledge Spaces

In the last years, growing attention has been paid to the generalization of KST deterministic concepts to the case of polytomous items. As a consequence of this extension, a generalized version of the basic local independence model (BLIM) has been recently proposed, named polytomous local independence model (PoLIM). Some of the main features of this new model have been investigated, but, to date, nothing has been specifically stated about its identifiability.
In this research we present the first theoretical results about the problem of identifiability of the PoLIM. Such results represent a generalization to this polytomous model of what has been proven about the identifiability of the BLIM, which is the most widely used probabilistic model in dichotomous knowledge space theory. The study of the identifiability of the BLIM produced several research articles in the last ten years, especially focusing on the relations between two particular kinds of gradation of the deterministic structure, called forward and backward gradedness, and the unidentifiability of the model when applied to such structures. Here we show that the same kind of gradedness happens to apply also to the case of polytomus structures, and further attention is paid to some properties of forward and backward gradedness in the case of polytomous structures. For instance, we show that in the polytomous case there is no need to distinguish between forward and backward gradedness, but it is possible to simply speak about gradedness. Moreover, we show how gradedness of the polytomous structure leads to the same kind of tradeoffs studied in the BLIM between the probability of knowledge states and the error parameters of the items in which the polytomous structure is graded. The tradeoff equations are displayed and further directions to study the identifiability of the PoLIM are discussed.

The dimension of a knowledge space

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Session:
Knowledge Spaces

The dimension of a partial order P on a set A is a well-known and thoroughly studied concept. It is defined as the smallest number of linear orders on A whose intersection equals P. It can also be characterized as the smallest family F of mappings f from A to the reals such that a P b if and only if f(a) is less or equal to f(b) for all the mappings in F. The interest for this characterization stems from the fact that it qualifies the problem of determining the dimension of a partial order as a measurement theoretical question (Roberts, 1985). The states in a knowledge structure and, in particular, in a knowledge space are partially ordered by set inclusion. Therefore the dimension of a knowledge structure is a well-defined concept, and it corresponds to the dimension of the restriction of the set inclusion relation to the knowledge structure itself. We show that, under a rather general condition, named "join escape", the dimension of a finite knowledge space equals the length d of a maximum antichain in its basis. If, for a given knowledge space, join escape does not hold, then d only provides an upper bound to the dimension of the knowledge space. It is further found that, under the stated condition, the dimension of a knowledge space coincides with the least number of maximal chains whose element-wise union reconstructs the entire knowledge space.

Narcissism and the social context: An agent-based modeling approach

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Session:
Dyad and Agent Modelling

Interpersonal psychological factors are - in addition to intrapersonal psychological factors - crucial for the development of mental health problems. Testing underlying factors of mental health problems for causality is difficult because they can hardly be manipulated experimentally. As a possible solution, we propose to use one major, in other research fields already approved cognitive modeling approach, called agent-based modeling (ABM). To illustrate the application of this approach in psychological research, especially clinical psychology, we develop a model based on the underlying factors of grandiose narcissism as personality trait and implement it as ABM. This way, we examine the characteristics that are crucial for the development of grandiose narcissism, focusing on the role of social interactions. To validate our findings, we evaluate the simulated data using a Social-Network-Analysis (SNA) approach and compare it with results of SNA from real data. After examining underlying factors, it is possible to derive possible interventions that can be tested using ABM. Our approach provides a promising example for applying ABM in psychological research, especially when examining interpersonal factors of mental health problems.

Mental model evolution in social networks

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Session:
Dyad and Agent Modelling

This paper investigates the impact of different mental models on the formation of belief clusters and the spread of opinions within social networks, using an agent-based model. Every behaviour can be grouped into two categories: fundamental and emergent behaviours. A fundamental behaviour is a property of an agent that is independent of other properties or agents, while emergent behaviours are caused by the interactions of fundamental or other emergent behaviours. This paper studies fundamental behaviours to understand which ones are better to explain the emergent behaviours that are empirically observed. In our simulations, agents interact within a randomly generated network and observe signals about whether climate change is real or is a conspiracy. Then, they use various mental models to update their beliefs, where mental models are defined as functions which agents employ to update their beliefs in response to new information. We create three mental models: a Bayesian updating rule which rational agents use, a heuristic-based updating rule which boundedly rational agents use, and a Dirac-Von Neumann rule which agents who can be irrational use. Furthermore, we use state-of-the-art random networks to understand how community structures respond to these mental models, how clusters are formed to represent conspiracy theory groups, and in which models conspiracy theory groups can grow by convincing rational agents. We aim to reveal which belief update methodologies tend to create more realistic clusters in which polarizations arise due to agents being resistant to novel information. Moreover, we explore if rational agents can end up believing in conspiracy theories under any community structure. This paper is the first one to study multiple belief update methodologies in social networks using agent-based modelling, allowing us to reveal novel behaviours of belief diffusion.

A formal model of affiliative interpersonality

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Session:
Dyad and Agent Modelling

Capturing the complexity of interpersonal dynamics – emerging from the approach and avoidance motives of two individuals in dyadic interplay that unfolds simultaneously on multiple time scales in order to satisfy their psychological needs – remains a scientific challenge. In line with calls for embracing complexity in psychological research using formal modeling, the purpose of this mathematical study is to investigate the underlying mechanisms of the formation and maintenance of affiliative interpersonal relationships using evolutionary game theory.
After formalizing interpersonal situations based on the affiliative motives of their interactants, a relational state space is constructed that reflects the ways of relating available to the interactants in the momentary state of their interpersonal relationship. This allows for modeling the evolution of an interpersonal relationship as a trajectory – driven by positive and negative reinforcement – in the relational space.
Depending on the motives of both interactants, three qualitatively different interpersonal dynamics emerge: (1) global stability with only one relational attractor (e.g., an interpersonal relationship of pure friendliness in the long run), (2) bistability with two mutually exclusive relational attractors (e.g., either pure friendliness or pure distance), and (3) cyclicality with periodic orbits in the relational space (e.g., oscillation between friendliness and distance).
Grounded in empirically supported psychological constructs, the formal model generates the well-known pattern of interpersonal complementarity. Over and above, novel interpersonal patterns emerged that might point to some underlying mechanisms of the interpersonal maintenance of psychopathology. The model limitations as well as avenues for empirical tests and further development are discussed.

A Cognitive Model of a Temporal Binding Task

Temporal binding (TB) is the subjective compression between a voluntary action and its associated outcome.
It is regarded as an implicit measure of the sense of agency; however, an underlying mechanism has yet to be agreed upon. Previous research suggests memory as an alternative explanation for TB in two publicly available datasets. Here, we test this idea by implementing a model within the ACT-R cognitive architecture and leveraging its existing memory and time perception mechanisms to simulate participants from these datasets. Our model simulations provide evidence to suggest that memory and time perception mechanisms can explain the pattern of results. Implications for temporal binding and the sense of agency will be discussed.

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Session:
ICCM: ACT-R

ACT-R Modeling of Rapid Motor Learning Based on Schema Construction

The environment surrounding organisms changes dynamically, and humans acquire motor skills by improving the prediction of such environmental changes. The research on cognitive architectures has so far proposed several mechanisms explaining the process of human motor learning. Adaptive Control of Thought-Rational (ACT-R), one of the representative cognitive architectures, has perceptual and motor modules for interaction with the external environment. However, the performance of these modules is insufficient for real-time environments, especially in terms of learning speed. This study proposes a method to simulate human-level rapid motor learning using a pre-trained motor learning module. We assume that in a novel perceptual-motor task, a pre-trained motor schema is rediscovered/recalled. In the simulations, we trained the motor learning module in advance and conducted a simulation where difficulties of rediscovering schemata were manipulated. As a result, we confirmed that the pre-trained phase increased the human-model fitting in motor learning.

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Session:
ICCM: ACT-R

An initial cognitive model of a radar detection task

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Session:
ICCM: ACT-R

In adversarial operational environments like radar monitoring, humans have to monitor large amounts of information, multitask, and manage threats. They may also face electronic disruption or attacks aimed at degrading radar monitor effectiveness (a.k.a electronic warfare or EW). In these settings, it is unclear how frequent changes in personnel, training, and updates to visual displays affect an operator's readiness. A recent experiment used an analogous radar monitoring task to investigate effects of display density and electronic warfare on an operator's threat detection performance. Here, we present a cognitive model capable of completing a scaled down version of that task to better understand the experimental results and underlying cognitive processes. Similar to the human experiment, our cognitive model completed conditions comprised of changes to the nature of the task(s), the number of targets to track, and the presence or absence of distractors, deemed 'friendlies'. Although this initial cognitive model uses primarily default ACT-R parameters, it was able to capture patterns in human performance across conditions. We present the results and discuss limitations to address in future work.

Improving Visuomotor Control of a Cognitive Architecture

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Session:
ICCM: ACT-R

Symbolic/hybrid computational cognitive architectures, including the ACT-R framework, are adept at capturing a wide variety of human cognitive processes and behaviors including problem-solving, memory, and language. However, such cognitive architectures do not capture visuomotor behaviors that tightly couple perceptual and motor processes – such as manual tracking. In this study, we aimed to improve the cognitive fidelity of manual tracking behavior within the ACT-R framework by implementing the position control model (PCM) – a continuous, linear control model that effectively captures human tracking behavior (Powers, 1978). We integrated PCM within a MATB task model developed within the ACT-R framework, to examine if the integrated ACT-R/PCM model showed improvement in capturing human tracking performance relative to the Standard ACT-R model. Results indicate that the ACT-R/PCM Integrated model showed improved performance in capturing certain aspects of human tracking behavior, in comparison to the Standard ACT-R model.

Long Road Ahead: Lessons Learned from the (soon to be) Longest Running Cognitive Model

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Session:
ICCM: ACT-R

We present a cognitive model that plays a video game of driving a bus for a long time. The model was built using the ACT-R cognitive architecture and an extension to support perceptual-motor knowledge of how to interact with the environment (VisiTor and ACT-R/PM). Our extension includes bitmap-level eyes and robot hands. The model was run for a long time, over 6 hours on the way from Tucson to Las Vegas. We employed a design approach based on the ADDIE model to create different knowledge representations and actions; the model's predictions can be matched to some aspects of human behavior on the fine details regarding the number of course corrections and average speed and learning rate. However, it does not exhibit the same level of fatigue as human behavior. This contrasts with the way humans typically perform such long tasks. This model shows that perception opens up new interfaces and provides a very accessible testbed for examing further aspects of behavior. and adding components of human behavior that remain missing from ACT-R.

Neither measurement error nor speed-accuracy trade-offs explain the difficulty of establishing attentional control as a psychometric construct: Evidence from a latent-variable analysis using diffusion modeling

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Session:
Evidence-Accumulation Models: Applications I

Attentional control refers to the ability to maintain and implement a goal and goal-relevant information when facing distraction. So far, previous research has failed to substantiate strong evidence for a psychometric construct of attentional control. This has been argued to result from two methodological shortcomings: (a) the neglect of individual differences in speed-accuracy trade-offs when only speed or accuracy is used as dependent variable, and (b) the difficulty of isolating attentional control from measurement error. To overcome both issues, we combined hierarchical-Bayesian Wiener diffusion modeling with structural equation modeling. We re-analyzed five datasets, which included data from three to eight attentional-control tasks and from young and older adults. Overall, the results showed that even when accounting for speed-accuracy trade-offs and removing measurement error, measures of attentional control failed to correlate with each other and to load successfully on a latent variable. These findings emphasize the necessity of rethinking attentional control.

The Role of Salience-Driven Attention on Multialternative Multiattribute Choice

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Session:
Evidence-Accumulation Models: Applications I

Attention has been shown to play a central role in decision-making and multi-alternative multiattribute choice. However, the role of attention has been elusive and characterized in different ways. In this project, we explore the role of attention by manipulating the salience of different options in a multi-alternative, multi-attribute choice display. We include two sets of trials. In one set of trials, there is a dominant option that is better on both attributes than the other alternatives. In the second set, we use attraction effect trials, where a target option dominates a decoy option but not a competitor. We observe that salience interacts with choice, where the salient option is selected more often, especially in quick decisions in both sets of trials. This suggests that salience plays an important role in the dynamics of multiattribute choice. We test different hypotheses for how salience-driven attention impacts preferences using an evidence accumulation modeling framework where the salient option is given an initial starting point boost or more attention is paid to comparisons with the salient option during deliberation.

Degenerate boundaries for multiple-alternative decisions

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Session:
Evidence-Accumulation Models: Applications I

Integration-to-threshold models of two-choice perceptual decision making have guided our understanding of human and animal behavior and neural processing. Although such models seem to extend naturally to multiple-choice decision making, consensus on a normative framework has yet to emerge, and hence the implications of threshold characteristics for multiple choices have only been partially explored. Here we consider sequential Bayesian inference and a conceptualisation of decision making as a particle diffusing in n-dimensions. We show by simulation that, within a parameterised subset of time-independent boundaries, the optimal decision boundaries comprise a degenerate family of nonlinear structures that jointly depend on the state of multiple accumulators and speed-accuracy trade-offs. This degeneracy is contrary to current 2-choice results where there is a single optimal threshold. Such boundaries support both stationary and collapsing thresholds as optimal strategies for decision-making, both of which result from stationary representations of nonlinear boundaries. Our findings point towards a normative theory of multiple-choice decision making, provide a characterisation of optimal decision thresholds under this framework, and inform the debate between stationary and dynamic decision boundaries for optimal decision making.

Frustration of the achievement motive: Insights from a diffusion model analysis

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Session:
Evidence-Accumulation Models: Applications I

The present study aims to replicate and extend the experiment conducted by Brunstein & Maier (2005) on the impact of performance feedback and the strength of the implicit achievement motive on task performance. Brunstein and Maier found that more achievement motivated individuals show a reduction in mean RTs when they get bogus negative intraindividual performance feedback. The reduction in mean RTs is interpreted by the authors as enhanced effort. This feedback by achievement motive interaction effect is cited as one key finding of motive literature. However, the effect has not yet been replicated. In our study, participants complete an attention task akin to the d2-R task while receiving either positive or negative bogus intraindividual performance feedback. The study has two primary objectives: firstly, to replicate the feedback by achievement motive interaction effect reported by Brunstein and Maier, and secondly, to gain a more detailed understanding of the cognitive processes involved using the diffusion model (Ratcliff, 1978). In addition to presenting the results from our replication study, we will show the results of a pre-study demonstrating the applicability of the diffusion model to the type of task employed by Brunstein and Maier. Overall, we argue that diffusion model analyses can help to gain a better understanding of the effects of achievement motive frustration.

A Spatially Continuous Diffusion Model of Visual Working Memory

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Session:
Evidence-Accumulation Models: Applications I

I present results from four or five visual working memory (VWM) experiments in which subjects were briefly shown between 2 and 6 colored squares. They were then cued to recall the color of one of the squares and they responded by choosing the color on a continuous color wheel. The experiments provided response proportions and response time (RT) measures as a function of angle for the choices. Current VWM models for this task include discrete models that assume an item is either within working memory or not and resource models that assume that memory strength varies as a function of the number of items. Because these models do not include processes that allow them to account for RT data, we implemented them within the spatially continuous diffusion model (SCDM, Ratcliff, 2018) and use the experimental data to evaluate these combined models. In the SCDM, evidence retrieved from memory is represented as a spatially continuous normal distribution and this drives the decision process until a criterion (represented as a 1-D line) is reached, which produces a decision. Noise in the accumulation process is represented by continuous Gaussian process noise over spatial position. The models that fit best from the discrete and resource-based classes converged on a common model that had a guessing/zero evidence component (a zero-drift process) and that allowed the height of the normal memory-strength distribution to vary with number of items. The combination of choice and RT data allows models that were not identifiable based on choice data alone to be discriminated.

The impact of warning cues on detection decisions in continuous monitoring situations

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Session:
Neuroscience II

In many real world situations, sensory events of interest might appear at any moment and require us to act. Perceptual decisions like these, especially when stimuli are ambiguous or noisy, are thought to be facilitated by the accumulation of perceptual evidence over time until reaching a decision bound - a criterion amount of evidence. Temporal uncertainty requires a fine balance between accumulating evidence for better accuracy while avoiding false-alarms based on noise alone, as well as accounting for the cost of continuously maintaining a state of readiness. The decision-maker can, however, use cues in the environment to make top-down dynamic adjustments of the decision-making process. Previous research has shown that cues can have multiple modulatory effects spanning the sensorimotor pathway, but how such effects translate to computational adjustments in the decision-making process remains unknown

Here, we examine the effect of external auditory warning cues, while participants indicated the direction (left/right) of intermittent 1.4-second periods of coherent motion targets within otherwise incoherent, continuously moving dots. Behavioural modelling showed that participants respond to the cue by quickly lowering their decision bound, which is supported by a shifting of electroencephalogram signatures of motor preparation (β power) towards an action-triggering bound as response to the warning cue. However, this is unlikely to be the only adjustment. We further explore additional adjustments looking at neural signatures tracing 1) basic sensory encoding of evidence strength (steady state visual motion evoked potentials; SSMEPs), and 2) evidence accumulation (centro-parietal positivity; CPP). In ongoing work, these signals allow us to map out the multiple effects of the cue on the decision-making processes, using neurally-informed modelling.

Dissecting time-varying decision dynamics in the basal ganglia: how the weighing of distinct sensory information contributes to task difficulty and perceptual conflict

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Session:
Neuroscience II

Perceptual decision-making evolves from interactions between cortical neurons which decode sensory information, and the basal ganglia which integrate across sources of information to prepare for action. The subthalamic nucleus (STN) dynamically controls the decision threshold, determining the necessary amount of corticostriatal evidence for response initiation. Past research focused on evidence accumulation models with fixed decision bounds, while neural data and biophysical simulations suggest that STN activity is highly dynamic. These dynamics may be mechanistically reflected by theta- and beta-band oscillations.

In this study, we aimed to use these e-phys biosignatures to determine if dynamic activity in the STN is mostly modulated by active conflict, task difficulty, or both. To do so, we recorded electrophysiological activity in the STN and globus pallidus (GP) of 17 patients with Parkinson's disease ($n = 14$) or dystonia ($n = 3$) during a direction discrimination task. Stimuli involved moving random-dot patterns that independently varied in motion strength (coherence), and motion direction (angular trajectory). These conditions separately manipulated task difficulty (easy, hard) and active conflict (low, high). Leveraging recent advances in likelihood-free inference, we tested the aforementioned aims by using a wide variety of sequential sampling models (SSMs). First, we found that models with Weibull-informed collapsing boundaries outperformed classical Diffusion Decision models, Ornstein-Uhlenbeck models, and models with linear collapsing boundaries. Second, motion strength coherence (difficulty) affected evidence accumulation (drift rate), while angular trajectory (active conflict) affected response caution (decision threshold). Finally, preliminary modeling results based on neural regressors suggest that within-trial dynamics of STN and GP theta and beta activity influence decision dynamics.

This study advances our understanding of how neural dynamics in the basal ganglia influence decision dynamics as a function of task difficulty and perceptual conflict. It has the potential to resolve some discrepancies in previous studies assuming a fixed decision boundary that is impacted by a single measure of neural activity.

Bayesian Decoding As A Testing and Development Link Between Behavioral and Neurological Models

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Session:
Neuroscience II

Formal models of behavior express or explain an expected relationship between stimuli and responses in a controlled (repeatable) experiment. Formal models in the behavioral neurosciences (more often, "computational models") describe, at one or more levels, such as neurotransmitter uptake, single neuron spike trains, or regions of the brain, the neurochemical events that lead to an activity downstream in the network, which is sometimes but not always the observable response. In both fields, the question why a given response is observed on a given trial is answered by reproducing the behavior or activity (statistically) in the model.
At least with respect to cross-communication and mutual benefits, there are two well-known problems with this shared paradigm. First, behavioral models are specified at a level of abstraction far beyond the level of neurological models. It is not obvious, therefore, whether there should be any relationship at all between the two constructions, or whether an apparent similarity is meaningful or constitutes 'evidence' to support the two theories. Second, neurological activity, even at the level of single neurons, is exceedingly complex, and this complexity is observable in minute detail. The idea of limiting the number of free parameters so that goodness-of-fit statistics can be compared is self-defeating from the outset.
In this paper/proposal, I will briefly explain how a relatively new statistical methodology in the neurosciences, called Bayesian decoding, can connect the two sciences in a rigorous manner. Basically, instead of asking what events give rise to intelligent behavior, the modeler asks what information about the stimulus and the possible responses is contained in the events that lead to the response, that is, what properties of these events can be predicted and to what degree.

The Penn Electrophysiology of Encoding and Retrieval Study

Kahana, Mike
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Session:
Neuroscience II

The Penn Electrophysiology of Encoding and Retrieval Study (PEERS) aimed to characterize the behavioral and electrophysiological (EEG) correlates of memory encoding and retrieval in highly practiced individuals. Across five PEERS experiments, 300+ subjects contributed more than 7,000 ninety-minute memory testing sessions with recorded EEG data. Here we tell the story of PEERS: it's genesis, evolution, major findings, and the lessons it taught us about taking a big science approach to the study of memory and the human brain. In particular, we focus on the role of big data in combining computational modeling approaches to cognitive with the study of individual differences.

On the best-worst choice model of Marley and Louviere

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Session:
Symposium In Honor of AAJ Marley

In the best-worst choice paradigm pioneered by Louviere (Finn and Louviere, 1992), the subjet is asked to select her best and her worst alternatives in any set of alternatives. Tony Marley conceived a random utility model providing a possible explanation for the choice frequencies (Marley and Louviere, 2005). He then asked for a characterization of the prediction range of the model, and since 2006 had been working from time to time on the problem with several collaborators (Samuel Fiorini, Mike Regenwetter, Reinhard Suck, and the speaker). The problem was quickly turned into the search of an affine description of the convex polytope formed by the model predictions. However, not much is known about the polytope. In the particular case of four alternatives, a description consists of 26 affine equalities and 144 affine inequalities (Doignon, 2023), and the Gale transform of the set of vertices fully reveals the polytope structure: the transform is a family of 24 vectors in a one-dimensional vector space. Thus the expert eye can read the full structure of the polytope from 24 vectors on a line. For more than four alternatives, Marley problem remains open.

The role of reinforcement learning in shaping the decision policy in methamphetamine use disorders

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Session:
Symposium In Honor of AAJ Marley

The prevalence of methamphetamine use disorder (MUD) as a major public health problem has increased dramatically over the last two decades, reaching epidemic levels, which pose high costs to healthcare systems worldwide and is commonly associated with experience-based decision-making (EDM) aberrant. However, precise mechanisms underlying such non-optimally in choice patterns still remain poorly understood. In this talk, to uncover the latent neurobiological and psychological meaningful processes of such impairment, we apply a reinforcement learning diffusion decision model (RL-DDM) while methamphetamine abuser participants ($nIdentifyingcontextsweetspots18$, all men; mean (±SD) age: 27.3 ± 5) and age/sex-matched healthy controls ($nIdentifyingcontexteffecr25$, all men; mean ($\pm SD$) age: $26.8.0 \pm 3.63$) perform choices to resolve uncertainty within a simple probabilistic learning task with rewards and punishments. Preliminary behavior results indicated that addicts made maladaptive patterns of learning that mirrored in both choices and response times (RTs). Furthermore, modeling results revealed that such EDM impairment (maladaptive pattern in optimal selection) in addicts was more imputable to both increased learning rates (more sensitive to outcome fluctuations) and decreased drift rate (less reward sensitivity) compared to healthy. In addition, addicts also showed substantially longer non-decision times (attributed to slower RTs), as well as lower decision boundary criteria (reflection of impulsive choice). Taken together, our findings reveal precise mechanisms associated with EDM impairments in methamphetamine use disorder and confirm the debility of the options values assignment system as the main hub in learning-based decision-making.

Best, worst, and best&worst choice probabilities for logit and reverse logit models

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Session:
Symposium In Honor of AAJ Marley

This paper proposes new models for analyzing best, worst, and best&worst choice probabilities for logit and reverse logit models, building on the pioneering work of Tony Marley. We assume individuals have a stochastic underlying ranking of alternatives and posit a rationality assumption relating to the random utility model. We focus on models applicable to best and worst choice scaling experiments, utilizing an inclusion-exclusion identity to propose a variety of best-worst choice probability models that can be implemented in specialized software packages. We demonstrate the versatility and utility of logit and reverse logit models in capturing the underlying ranking of alternatives. Finally, we discuss the practical implications of these models and future research directions in this field. Our models can be implemented in popular software packages such as Apollo.

An integrated choice and response time decision field theory model: new insights on choice response times in multi-attribute, multi-alternative choice.

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Session:
Symposium In Honor of AAJ Marley

Decision field theory (DFT), although popular in mathematical psychology, has only recently been used in choice modelling for consumer and travel choices. A key difference that DFT has from standard choice models is that it has preference values for each alternative that update over the course of the decision-making process. This results in a different probability of picking each alternative depending on how long a decision-maker considers their alternatives. However, the computational complexities of DFT have resulted in failures to utilise its dynamic nature. Recent advances in the underlying computational methods for DFT have allowed for the calculation of the probability of choosing alternatives at any time point. Consequently, the number of preference accumulation steps can be linked to the choice response time. In the work in this paper, we develop an integrated choice and latent variable decision field theory model to predict choice responses and choice response time. We use these models to explore the confounding nature of choice response time. A key assumption within DFT and other accumulator models is that preference grows over time, contradicting a well-known result that a longer response time often indicates a less certain and hence less deterministic choice from a decision-maker. In line with DFT and preference accumulation, we find that across model results from three datasets, a longer mean response time indicates that a decision-maker appears more deterministic. However, within a decision-maker, our models suggest that fast decisions are typically more deterministic, demonstrating that a longer response time indicates a less certain decision. Whilst there is a weak correlation between choice response time and the estimated number of preference updating steps, results from multinomial logit (MNL) models suggest that DFT's time parameter performs a similar function to an MNL's scale parameter. This suggests that caution is required in interpreting the outputs from accumulator models.

Machine Learning approaches to estimating and comparing models of intertemporal choice

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Session:
Symposium In Honor of AAJ Marley

Subjective value has long been measured using binary choice experiments to assess individual differences in intertemporal preferences. Dynamic, stochastic models of choice permit meaningful inferences about cognition from process-level data, explaining value in terms of underlying mechanisms in a way that simpler, static models cannot. However, the usability of complex generative models is severely limited by the technical difficulty of model fitting and model comparison steps, along with the computational power they require. In this talk, we develop and test an approach that uses deep neural networks to estimate the parameters of three behavioral models and perform model comparison between the three to assess their ability to better account for intertemporal choice. The models we explore differ in their complexity and the theoretical assumptions they make when it comes to the study of preference; the traditional and static hyperbolic discount and hyperboloid functions compared with a probabilistic attribute-wise model constructed by direct and relative differences in delay and payoff. Once trained, the neural networks allow for accurate and instantaneous parameter estimation and model comparison, as opposed to traditional methods that can take several hours and in some cases days. We compare different network architectures and show that they are able to accurately recover true intertemporal preferences related to each model's parameters, and then compare each model's performance in their ability to predict individual choice. The models were applied to a large data set of substance users in protracted abstinence from Sofia, Bulgaria who completed a short, 27-question choice task. The results illustrate the utility of machine-learning approaches for wider adoption and integration of cognitive and economic models, providing efficient methods for quantifying meaningful differences in intertemporal preferences from simple experiments.

Preference estimation from point allocation experiments

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Session:
Symposium In Honor of AAJ Marley

Point allocation experiments are widely used in the social sciences. In these experiments, survey respondents distribute a fixed total number of points across a fixed number of alternatives. This paper reviews the different perspectives in the literature about what respondents do when they distribute points across options. We find three main alternative interpretations in the literature, each having different implications for empirical work. We connect these interpretations to models of utility maximization that account for point and budget constraints and investigate the role of budget constraints in more detail. We show how these constraints impact the regression specifications for point allocation experiments that are commonly used in the literature. We also show how a formulation of a taste for variety as entropy that had been previously used to analyse market shares can fruitfully be applied to choice behaviour in point allocation experiments.

Do Discrete Choice Experiments and Rating Scales Elicit the Same Preference Judgments?

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Session:
Symposium In Honor of AAJ Marley

Discrete choice (DCE) and rating scale experiments (RSE) are commonly applied procedures for eliciting preference judgments in a plethora of applied settings such as consumer choices, health care, and transport economics. An almost universal assumption underlying their use is that the two procedures elicit reports generated from a common internal preference state; that is, actual "ground truth" preferences are not dependent on which procedure is used to elicit them. It is usually not possible to test this assumption, because typical studies using DCE and RSE methods have response options for which there is no objectively correct response, and no ground truth. To facilitate a comparison of DCE and RSE, we conducted a perceptual discrimination experiment where response options varied on a single attribute – stimulus saturation level – with a known objectively correct response. We had the same participants complete both a DCE and RSE version of the experiment, allowing a direct examination of the assumption that a common representation underpins responses in both. For this purpose, we developed a cognitive model with a response mechanism for both DCE and RSE based on latent Gaussian stimulus representations. This enabled us to compare a model version that featured one shared latent stimulus representation across DCE and RSE versus a model version which featured a separate latent representation for DCE and RSE. Our results support the assumption that a single internal state supports both DCE and RSE responses, and also suggest that the DCE method might provide more sensitive measurement of internal states than the RSE method.

The role of decoy effects in nudging preferences for electric vehicles: A novel approach to fuse preference data with and without eye-tracking

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Session:
Symposium In Honor of AAJ Marley

Eye-tracking data such as the gaze patterns reveal important attention-related information about the evidence accumulation process in stated preference (SP) experiments but can only be collected in the lab with a relatively limited number of subjects owing to time and resource constraints. On the other hand, the online SP experiments offer a large sample size but at the expense of eye movement data. Extant literature uses online and lab-based eye-tracking data in isolation. This study develops an approach to elicit consumer preference by jointly leveraging both datasets and validatie it by collecting stated preferences of Singaporean ride-hailing drivers to rent electric vehicles in lab-based ($N = 40$) and online/street-intercept ($N = 300$) choice experiments. This study is relevant in the local context due to the very high cost of vehicle ownership.

To explore the general and accountable interactions between decoy effect strength, attention, and preference formation, an improved Multi-attribute Linear Ballistic Accumulator model concerning absolute attribute value with hierarchical structure (henceforth, HA-MLBA) is adapted and calibrated using both lab-based and online datasets. Specifically, the posterior distribution of HA-MLBA parameters estimated by lab-based data is considered as the prior distribution for the corresponding parameters (including process, alternative-specific parameters, and attribute-specific parameters) while estimating HA-MLBA using online data. To highlight the superiority of this data fusion method, in-sample and out-of-sample performances in fitting choice and response time distribution of the HA-MLBA model with non-informative prior (baseline) and data-fusion prior (informative) are compared. This research demonstrates the presence of the decoy effects (similarity effect and Attraction Effect particularly) in the vehicle rental market. With the increased online purchase of vehicle rentals, such context effects could be vital in nudging ride-hailing drivers to adopt electric vehicles.

Cube model: Predictions and account for best-worst choice situations with three choice alternatives

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Session:
Symposium In Honor of AAJ Marley

The Cube model (Mallahi-Karai and Diederich, 2019) is a dynamic-stochastic approach for decision making situations including multiple alternatives. The underlying model is a multivariate Wiener process with drift, and its dimension is related to the number of alternatives in the choice set. Here we modify the model to account for Best-Worst setting. The choices are made in a number of episodes allowing the alternatives to be ranked from best to worst or from worst to best. The model makes predictions with respect to choice probabilities and (mean) choice response times. We show how the model can be implemented using Markov chains and test the model on data from (Hawkins et al., 2014b).

Safe anytime live and leading interim meta-analysis

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Session:
Statistics and Individual Differences

In this talk we introduce the Anytime Live and Leading Interim (ALL-IN) meta-analysis approach that allows experimenters to adaptively design multi-lab replication experiments in a safe manner. In this context, safe refers to the fact that the procedure comes with explicit guarantees regarding the tolerable type I error rate *during* data collection.

This approach to meta-analysis is based on a so-called meta e-value that combines the currently available evidence across all studies. At any moment in time, experimenters can safely consult this meta e-value to decide whether it is worthwhile to (i) extend the meta-analysis with another (replication) study, (ii) continue recruiting participants in the currently active studies, or (iii) stop the data collection of all studies, because the combined evidence is already compelling. It is important to note, that despite this data-driven approach leading to interdependent studies, the statistical inferences from ALL-IN meta-analyses remain valid.

This is unfortunately not the case for conventional meta-analyses based on p-values and confidence intervals, because, when used adaptively, they over-inflate the type I error, thus, have a high chance of mistaking random noise for structural effects. Statistical reliable use of conventional methods, therefore, requires experimenters to confine themselves to rigid designs, in which a meta-analysis is only conducted retrospectively once all –either too few, or too many– studies are completed.

The ALL-IN procedure frees experimenters from the statistical shackles imposed by conventional methods and empowers them with a more flexible, efficient, and safe approach to conducting meta-analyses.

Robust Bayesian Meta-Regression: Publication bias adjusted moderator analysis

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Session:
Statistics and Individual Differences

Publication bias is a well-recognized threat to research synthesis. Although a variety of models have been proposed to adjust for publication, no single model performs well across different meta-analytic conditions (Carter et al., 2019; Hong & Reed, 2021). One possible remedy to this problem lies in Bayesian model averaging with Robust Bayesian Meta-Analysis (RoBMA; Maier et al., 2022). RoBMA addressed publication bias by averaging over 36 candidate models of the publication process and was shown to perform well under diverse conditions (Bartoš et al, 2022). In this talk, we extend RoBMA to meta-regression settings. The newly introduced moderator analyses enable testing for the presence as well as the absence of continuous and categorical moderators using Bayes factors. This advances existing frequentist methodologies by allowing researchers to also make claims about evidence for the absence of a moderator (rather than the mere absence of evidence as implied by a nonsignificant p-value). Furthermore, RoBMA's meta-regression does not only model average over the different publication process models, but also over the included moderators. Consequently, researchers can draw inferences about each moderator while accounting for the uncertainty in the remaining moderators. We evaluate the performance of the developed methodology in a simulation study and illustrate it with an example.

Temporal structure in sensorimotor variability is a reliable trait, but is unrelated to attentional state measures

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Session:
Statistics and Individual Differences

Behavioural performance shows substantial endogenous variability over time, regardless of the task at hand. This intra-individual variability is a reliable marker of individual differences. Of growing interest to psychologists is the realisation that variability is not fully random, but typically exhibits short- and longer-range temporal structures. However, the measurement of temporal structures come with several controversies, and their potential benefit for studying individual differences in healthy and clinical populations remains unclear. The interpretation of these structures is also controversial. Behavioural variability is often implicitly associated with fluctuations in attentional focus, which also fluctuates over time between on- and off-task (e.g., "I was performing poorly because my mind was wandering elsewhere"). However, empirical evidence for this intuition is lacking. In the current research, we analyse the temporal structures in reaction (RT) series from new and archival datasets, using 11 different sensorimotor and cognitive tasks across 526 participants. We first investigate the intra-individual repeatability of the most common measures of temporal structures. Secondly, we examine inter-individual differences in these measures using: 1) task performance assessed from the same data, 2) meta-cognitive ratings of on-taskness from thought probes occasionally presented throughout the task, and 3) self-assessed attention-deficit related traits. Across all datasets, autocorrelation at lag 1 and Power Spectra Density slope showed high intra-individual repeatability across sessions and correlated with task performance. The Detrended Fluctuation Analysis slope showed the same pattern, but less reliably. The long-term component (d) of the ARFIMA(1,d,1) model showed poor repeatability and no correlation to performance. Overall, these measures failed to show external validity when correlated with either mean subjective attentional state or self-assessed traits between participants. Overall, temporal structures may be stable within individuals over time, but their relationship with subjective state and trait measures of attentional state remains elusive.

g-distance: A new framework for comparison of model and human heterogeneity

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Session:
Statistics and Individual Differences

This work explores model adequacy as a function of heterogeneity, prediction and a priori likelihood. Models are often evaluated when their behaviour is at its closest to a single group-averaged empirical result. This evaluation neglects the fact that both models and humans are heterogeneous. Models' and humans' behavioural repertoire is not restricted to a single unit of behaviour but is composed of a range of distinguishable behaviours - ordinal patterns. In this framework, we develop a measure, g-distance, that considers model adequacy to be the extent to which models exhibit a similar range of behaviours to the human behaviours it models. We then continue to apply this framework to models of an irrational learning effect, the inverse base-rate effect. We include 6 models in our model comparison. In the process of analysing the human data, we show that the canonical averaged group-level empirical result hides theoretically important and robust relationships between pairs of stimuli. These are amongst the most commonly observed ordinal results on a subject level. Models are unable to accommodate these relationships. They all perform unanimously poorly in our benchmark. In addition, the model that best accommodates human behaviour also predicts almost all unobserved possible behaviours. We show that all models unanimously predicted many more unobserved behaviours than accommodated already observed behaviours. We discuss these sets of results in terms of how well they approximate human behaviour in the inverse base-rate paradigm if most of the behaviours they produce are not exhibited by humans. Finally, we propose various new avenues for formal computational modelling by clearly defining a handful of scientific problems.

Detecting multiple sequential decisions within a single trial using EEG

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Session:
Symposium: Investigating Within-Trial Timing of Cognitive Processes with EEG

Simple decision processes can be regarded as one of the most important building blocks of behavior. A decision process is here defined as any cognitive process that develops over time and results in a conceptual representation. This includes – but is not limited to – a decision that results in the representation of a course of action, a decision on the content of a perceptual object, and a decision on the meaning of a perceived word. Although current state-of-the-art evidence accumulation models (EAMs) are excellent predictors of behavior that is determined by single decisions, they cannot be used to investigate multiple sequential decisions. It therefore remains unclear how latent decision processes influence subsequent cognitive processes and decisions, and ultimately overt behavior. This has resulted in a lack of understanding of behavior that involves a sequence of decisions – which is imperative, as this is a situation that occurs almost immediately when addressing slightly more complex laboratory tasks, let alone when leaving the lab to investigate real-life situations.
In this presentation, we discuss a novel approach in which we first apply machine learning to discover sequential processing stages in EEG data (called Hidden semi-Markov Modeling and Multivariate Pattern Analysis or HMP) and then characterize the duration effects in such identified stages using EAMs. This approach leads to a more fine-grained understanding of decision processes by demarcating the relevant processing stage. Moreover, it allows for understanding multiple decision processes in a single trial that are convoluted in behavior.

When does evidence accumulation begin after a visual stimulus? Evidence from neurocognitive modeling of EEG and behavior

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Session:
Symposium: Investigating Within-Trial Timing of Cognitive Processes with EEG

My previous work has focused on the possibility that Event-Related Potentials (ERPs) recorded with electroencephalography (EEG) can reflect the beginning of evidence accumulation during speeded decision making. Specifically, N200 peak latencies, negative local peaks in occipital-parietal electrodes around 180 ms, are thought to reflect this onset. I discuss why this matches convergent findings in the literature, and why evidence accumulation is not likely to begin immediately after visual information reaches the occipital cortex in most decision-making tasks. I discuss our recent findings on replication of this work with multiple new sources of data, including a preregistered data set. The replication work was performed with a number of analysis procedures, ranging from: basic regressions of N200 latency estimates compared to various Non-Decision Time (NDT) estimates, to fitting neurocognitive models that predict both choice-response times and single-trial N200 latencies. Multiple datasets were used to assess the theory of N200 latencies reflecting evidence accumulation onsets. The results are presented in the context of the best modeling procedures that generate inference about the truth of N200 latencies, as judged in simulation. We use hierarchical Bayesian modeling, simulation-based Bayesian inference, and computational models of ERPs. While little support was found for a 1 ms to 1 ms correspondence between NDTs and N200 latencies, significant positive relationships were found in most analysis procedures and datasets. I discuss what this means for the theory of the beginning of evidence accumulation during visual tasks. I also discuss the future of understanding ERPs in terms of their computational role in cognition.

Untangling frequency and word type effects on lexical decision processes

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Session:
Symposium: Investigating Within-Trial Timing of Cognitive Processes with EEG

Many studies have reported that word frequency influences language processing. For example, the lexical decision (LD) - deciding whether a character string is a word or not - becomes faster and more accurate when word frequency is increased. Yet, our understanding of the precise way continuous changes in frequency impact the different cognitive processes involved in reaching LDs remains limited. To address this, we conducted an EEG LD study in which we manipulated the continuous frequency of Dutch words and non-words (pseudo words and random character strings) and observed the impact on the duration of LD processing stages using a recent machine learning technique.
To obtain frequency scores compatible with words and non-words we relied on Google result counts. The trial-level duration estimates of LD processing stages were recovered from EEG using a combination of Hidden semi-Markov models and multivariate pattern recognition (Anderson et al., 2016, Psychol. Rev.). These duration estimates for each processing stage were then analyzed using generalized additive mixed models. We included (potentially nonlinear) effects of frequency and word type as predictors.
Confirming previous research, we found evidence for six processing stages. For the first three processing stages (0-70, 70-150, 150-240 ms) stage duration increased for more frequent stimuli. However, already in these earliest stages the effect of frequency differed slightly yet reliably between word types. For the last three processing stages we observed more complex effects of frequency and word type. In contrast to earlier findings, this suggests that frequency has an effect on virtually every process involved in LD, including the earliest ones likely related to visual processing and orthographic encoding.

Linking stages of conflict-processing across behavioral and electrophysiological data

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Session:
Symposium: Investigating Within-Trial Timing of Cognitive Processes with EEG

In the arrow flanker task (Eriksen & Eriksen, 1974), participants have to respond to a central target stimulus while ignoring irrelevant flankers. Mathematical models of conflict processing in the task assume that the response selection process is affected by the processing of interfering flankers until those have been inhibited. For example, the dual-stage two-phase (DSTP) model assumes that attention is in a first stage evenly distributed across the target and flanking stimuli and in the second stage focused solely on the target once irrelevant flankers have been inhibited. In contrast, the shrinking spotlight (SSP) model assumes that attention gradually shifts toward the target stimulus (White et al., 2011). Although both models capture main trends in behavioral data, little is known about how they relate to electrophysiological correlates of conflict resolution and response selection such as the stimulus-locked lateralized readiness potential (sLRP).
Using data from 150 participants who completed an arrow flanker task while their EEG was recorded, we integrated parameters of the two mathematical models and electrophysiological correlates of conflict resolution (sLRP peak latencies) in a multi-layer structural equation model framework. Parameters of the mathematical models and electrophysiological correlates of conflict resolution were meaningfully related to each other and demonstrated convergent validity. Both models produced comparable results, but the DSTP model was found to be superior to the SSP model in mapping to ERP measures that reflect sequential processing stages. The findings suggest that both models can help understand how individuals resolve conflicting stimuli, and the DSTP model may be more easily related to electrophysiological measures that capture sequential processing stages.

Modulations of theta frequency for cognitive control in behavior and in EEG

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Session:
Symposium: Investigating Within-Trial Timing of Cognitive Processes with EEG

Neural oscillations at theta frequency (4-8 Hz) are thought to play an important role in guiding behaviour (Cavanagh & Frank, 2014), a phenomenon sometimes labeled as cognitive control. In particular, theta amplitude increases when an unexpected event happens or something goes wrong. However, the computational role of theta has remained unclear. We present a computational model of how theta guides faster (gamma) frequencies, thus to synchronize (functionally, attend to) specific neural modules. In this model, theta amplitude and theta frequency are two dimensions that can be controlled for optimal cognitive control.
The model predicts that theta frequency decreases when a more difficult task is upcoming, because slower waves allow more time for competing representations to settle. This decreased frequency should be visible in both neurophysiology (measured via EEG) and behavior (measured via accuracy). In line with model simulations, we find empirically in the EEG spectrum that a cue predicting an upcoming difficult (relative to easy) stimulus, leads to an decreased theta frequency. Similarly, theta frequency measured at the behavioral level is slowed down on such difficult stimuli. This result demonstrates how different aspects of theta oscillations (amplitude and frequency) can be recruited for cognitive control, and how they can be manifested in EEG and behavior.

Are you sure? Modelling Local Confidence of a Driver

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Zgonnikov, Arkady

Session:
Confidence

When a person makes a decision, it is automatically accompanied by a subjective probability judgment of the decision being correct, in other words, a (local) confidence judgment. Confidence judgments have among other things an effect on justifications of future decisions and behaviour. A better understanding of the metacognitive processes responsible for these confidence judgements could improve behaviour models. However, to date there is little to no applied research done into confidence in dynamic environments as for example driving. Confidence judgments are mostly studied in a fundamental manner, focusing on confidence in simplistic perceptual or preferential tasks. At the same time, cognitive models of decision making of drivers have not accounted for confidence judgments yet. In this study, we made a first attempt of connecting these two fields of research by investigating the confidence of human drivers in left-turn gap acceptance decisions in a driver simulator experiment ($N = 17$). The study aimed to, firstly, investigate if confidence can be properly measured in a dynamic task. Secondly, it sought to establish the relationship between confidence and the characteristics of a traffic situation, in this study constituting the gap size described by the time to arrival of and distance to oncoming traffic. Thirdly, we aimed to model the dynamics of the underlying cognitive process using the evidence accumulation approach. We found that self-reported confidence judgements displayed a similar pattern as expected based on the earlier fundamental studies into confidence. Specifically, confidence increased with the gap size when participants decided to accept the gap, and decreased with gap size when the gap was rejected. Moreover, we found that confidence judgments can be captured through an extended dynamic drift diffusion decision model. In our model, the drift rate of the evidence accumulator as well as the decision boundaries are functions of the dynamic perceptual information perceived by the decision-maker. The model assumes that confidence ratings are based on the state of the accumulator after post-decision evidence accumulation. Overall, the study confirms that principles known from the fundamental research into confidence also hold for dynamic applied tasks.

Magnitude-sensitive sequential sampling models of confidence

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Session:
Confidence

Magnitude-sensitivity refers to the effect that decisions between two alternatives tend to be faster when the intensities of both alternatives (e.g., luminance, size, or preference) are increased even if their difference is kept constant. Previous studies proposed several computational models to describe decision and response time distributions in experimental paradigms with changes of stimulus magnitude. However, with only responses and response times as dependent variables, there was a high degree of model mimicry. We suggest to include confidence judgments as an additional dependent variable in experiments and models. We present three experiments, two brightness discrimination tasks and a motion discrimination task, in which the intensities of both alternatives were varied and confidence judgments were recorded. Under some stimulus manipulations, confidence increased with stimulus magnitude while accuracy remained constant. We generalized several previously proposed dynamical models of confidence and response time to account for magnitude-sensitivity by adding intensity-dependent noise parameters. We fitted each model to the data and compared models quantitatively. The intensity-dependent dynamical weighted evidence, visibility and time model (iddWEVT) was best in fitting the joint distribution of response times, choice and confidence judgments for the different experimental manipulations. Previous studies explained increasing confidence but constant accuracy with stimulus magnitude by a positive evidence bias, i.e. for the computation of confidence, people might rely only on the evidence supporting their decision and ignore evidence for the alternative. However, sequential sampling models offer an alternative explanation for these effects by considering the dynamics of a decision and by taking response times into account in the computation of confidence. We suggest that identification of computational models of decision making but also models of confidence can be improved by considering decisions, reaction times, and confidence at the same time.

Evidence accumulation explains the duration of perceptual experience and its associated confidence

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Session:
Confidence

Evidence accumulation is a fundamental process whereby noisy sensory information is accumulated over time up to a threshold. Although numerous studies have explored the link between evidence accumulation and decision formation, its contribution to perceptual consciousness remains unclear. Here, we propose a leaky evidence accumulation model that accounts for qualitative aspects of perceptual experience such as its perceived onset and duration, as well as confidence in perceptual judgments. Our model assumes that the onset of perceptual experience (i.e., stimulus detection) is triggered by the crossing of a perceptual bound by the accumulation process. Crucially, we hypothesized that perceptual experience lasts as long as accumulated evidence remains above the threshold, and that confidence is read out from the maximum reached by accumulated evidence over time. We tested these predictions in a pre-registered computational modelling study. Four healthy participants were asked to detect 3500 faces with different intensities and durations and either report their confidence in having perceived a face or no face or reproduce the duration of their perceptual experience of a face. As predicted, participants detected better and faster stimuli with high intensity or longer physical durations. Similarly, faces presented at high intensity or long duration were perceived with longer subjective durations and higher confidence. We fitted our computational model to response times and detection performance using the Variational Bayesian Monte Carlo toolbox. Using this model, we could parsimoniously reproduce effects of stimulus intensity and duration on perceived duration and confidence better than with alternative models that were not based on leaky evidence accumulation. Together, these results support leaky evidence accumulation as a mechanism explaining stimulus detection, but also some phenomenal aspects of perceptual experience such as subjective duration and confidence.

Computational models of decision confidence for uni- and multi-dimensional perceptual decisions

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Session:
Confidence

Decision confidence plays a crucial role in humans' capacity to make adaptive decisions in a noisy perceptual world. Often, our perceptual decisions, and the associated confidence judgements, require integrating sensory information from multiple modalities. Empirical investigation of the cognitive processes used for decision confidence under these conditions, however, has been severely limited. To bridge this gap, in this study we investigated the computations used to generate confidence when a decision requires integrating sensory information from both vision and audition and the extent to which these computations are the same when sensory information is solely visual or auditory. Participants ($N = 10$) completed three versions of a categorisation task with visual, auditory or audio-visual stimuli and made confidence judgements about their category decisions. In each version of the task, we varied both evidence strength, (i.e., the strength of the evidence for a particular category) and sensory uncertainty (i.e., the intensity of the sensory signal). We evaluated several classes of models which formalise the mapping of evidence strength and sensory uncertainty to confidence in different ways: 1) unscaled evidence strength models, 2) scaled evidence strength models, and 3) Bayesian models. Our model comparison approach therefore, provides a compelling specification of the class of algorithms used for decision confidence both when a signal has multiple perceptual dimensions and a single perceptual dimension. Where the signal had multiple perceptual dimensions, we were able to specifically quantify how both evidence strength and sensory uncertainty are integrated across modalities and the extent to which this integration was biased towards a particular modality. Furthermore, by generating predictions from the unidimensional signals and comparing these predictions to behaviour from the multidimensional signals, we determine the extent to which the computations used for decision confidence directly generalise across different decisional contexts.

Measures of metacognitive efficiency across cognitive models of decision confidence

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Session:
Confidence

Meta-d'/d' has become the quasi-gold standard to quantify metacognitive efficiency in the field of metacognition research because it has been assumed that meta-d'/d' provides control for discrimination performance, discrimination criteria, and confidence criteria even without the explicit assumption of a specific generative model underlying confidence judgments. Here, I show that only under a very specific generative models of confidence, meta-d'/d' provides any control over discrimination performance, discrimination criteria and confidence criteria. Simulations using a variety of different generative models of confidence showed that for most generative models of confidence, there exists at least some combinations of parameters where meta-d'/d' is affected by discrimination performance, discrimination task criteria, and confidence criteria. The single exception is a generative model of confidence according to which the evidence underlying confidence judgements is sampled independently from the evidence utilized in discrimination decision process from a Gaussian distribution truncated at the discrimination criterion. These simulations imply that previously reported associations with meta-d'/d' do not necessarily reflect associations with metacognitive efficiency but can also be caused by associations with discrimination performance, discrimination criterion, or confidence criteria. It is argued that decent measures of metacognition require explicit generative model of confidence with decent fits to the empirical data.

A pipeline for analyzing decision-making processes in a binary choice task

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Session:
ICCM: Decision Making

In this study, we propose a roadmap for the analysis of various factors on cognitive models' parameters and utilizing different cognitive models to better understand the human decision making process in a binary choice task. Our experiment of a binary choice task is a biased coin flip game, where users predict the outcome of 150 trials of biased coin flips without knowing the coin's bias. In a previous study, we conducted a factorial ANOVA on the biased coin flip game to identify factors that significantly influence users' decision making strategies, such as Gender, Win rate visibility, and the coin's bias value. In this paper, we employed genetic algorithms to identify cognitive models that fit users' behaviors the best in specific scenarios for each combination of the effective factors. Subsequently, we fitted linear models to examine the relationship between the identified parameters and the influential factors. By analyzing and interpreting the coefficients of these linear models, we aim to gain insights into how these factors affect users' decision making processes and understand human decision making better. Our proposed roadmap serves as a valuable resource for researchers aiming to interpret cognitive model parameters for diverse user behaviors. By providing a systematic approach to investigating the relationships between influential factors and cognitive model parameters, this work provides a deeper understanding of human decision making processes and baselines for future modeling approaches in this domain.

A Straightforward Implementation of Sensorimotor Abstraction in a Two-Layer Architecture for Dynamic Decision-Making

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Session:
ICCM: Decision Making

Cognitive and sensorimotor functions are usually assessed separately and therefore also modeled individually although they are strongly intertwined. One way to link these two levels conceptually is sensorimotor abstraction. It is the simplification of complex sensorimotor experiences, and it might enable goal-directed planning in situations with high uncertainties. We propose a computational model for dynamic decision-making that employs two distinct layers, a (lower) sensorimotor control layer holding sub-symbolic information, and a (higher) cognitive control layer holding abstracted information as symbols. In this two-layer architecture information about action control is passed upwards in the hierarchy, abstracted, and used to generate explicit action intentions which are passed downwards again. The hierarchization of model components is intended to represent the different levels of regulatory control (automated vs. fully conscious). We also use different forms of modeling for the individual layers. We employ predictive coding for sensorimotor and ACT-R for cognitive control. An agent equipped with the two-layer architecture is situated in a grid world and tasked to reach a finish line. However, the environment poses challenges on motor control by causing perturbations in the action execution of traversal reflecting varying uncertainty encountered in the real world. Here we describe a straightforward approach to the multi-layer architecture and relate it to the embodied cognition perspective. We also discuss possible extensions that we plan to introduce which depict fundamental cognitive functions such as representing the visual environment in varying granularity.

Comparing Classical and Quantum Probability Accounts of the Interference Effect in Decision Making

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Session:
ICCM: Decision Making

Prior research has found interference effects (IEs) in decision making, which violate classical probability theory (CPT).
We developed a model of IEs called the probability theory + noise (PTN) model and compare its predictions to an existing quantum model called the Belief-Action Entanglement (BAE) model. The PTN assumes that memory operates consistently with CPT, but noise in the retrieval process produces violations of CPT. Using parameter space partitioning, we identified that both models can produce all qualitative patterns of IEs. We found that the BAE tends to produce IE distributions with a larger variance compared to the PTN. We also show that PTN predicts a relationship we term the conditional attack probability equality (CAEP) which is violated in previously reported data. The CAEP holds for the PTN regardless of chosen parameter values. However, the BAE is not constrained by the CAEP.

Quantifying performance in magnitude comparison tasks using a drift-diffusion model

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Session:
ICCM: Decision Making

We investigate the viability of the drift-diffusion framework to account for behaviour on magnitude comparison tasks. Data from both published studies on magnitude comparison and a simulation are analysed to estimate the key drift-diffusion model parameters, using the EZ-diffusion method and HDDM package. All methods resulted in linear mappings between drift rate and difficulty (indexed using 1 - smaller/larger), with an intercept that was consistently close to zero for non-symbolic tasks. The EZ method was rapid and simple to apply, but subject to bias when using aggregate data or when accuracy was very high. In contrast, the HDDM tool produced results that were less biased, but individual differences were under-estimated. We conclude that application of parameter estimation methods, particularly in research on individual differences, requires careful consideration of their limitations.

Towards a Generalized Bayesian Model of Category Effects

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Session:
Categorization

An individual stimulus from a category is often judged to be closer to the center of that category than its true location. This effect has been demonstrated across different domains of perception and cognition and has been explained by the Category Adjustment Model (CAM; Huttenlocher et al., 2000), which posits that humans optimally integrate noisy stimuli with prior knowledge to maximize their average accuracy. Subsequent extensions to CAM have been proposed to account for more complex category effects, such as when there is more than one category involved or when prior knowledge involves multiple levels of abstraction. However, the question remains whether there exists an underlying general framework for the way people perceive categories across different tasks. To fill this gap, we propose a generalized Bayesian model of category effects, called the generalized CAM model (g-CAM). We demonstrate that CAM and its previous extensions are special cases of g-CAM, and that g-CAM can additionally capture novel experimental effects involving atypical examples.

Time pressure affects response precision but not psychological similarity in inferences from multiple features

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Session:
Categorization

People excel in categorizations–even under time pressure. We investigated how the human mind copes with time pressure during category inference by comparing three cognitive mechanisms within a framework, in which inferences about new objects are informed by similar previous objects. Specifically, we tested whether time pressure causes people to focus their attention to fewer object features, to respond less precisely, or to simplify the similarity computation by counting the number of differing features between objects but ignoring the precise feature value differences. To this end, we collected experimental data in the domains of categorization and similarity judgments and combined inferential statistics and computational cognitive modeling within the exemplar-similarity framework. In the categorization experiment, participants ($N = 61$) solved a trial-by-trial supervised, binary category learning task without time pressure, followed by unsupervised transfer categorizations with individually-calibrated time pressure for half the participants ($M = 902$ ms). The experimental design was optimized in simulations to maximally discriminate between the formal models in the transfer task. The results show that participants categorized the transfer stimuli less consistently with than without time pressure. In turn, we found no credible evidence that time pressure induced an attention focus or a simplified similarity. In the similarity judgment experiment, participants ($N = 175$) rated on a slider the similarity of various stimulus pairs once without time pressure and once with an individually-calibrated time pressure, manipulated across participants to be either weak ($N = 64, M = 2018$ ms), medium ($N = 55, M = 1225$ ms), or strong ($N = 56, M = 510$ ms). The results corroborate those from the categorization experiment, strongly suggesting that time pressure lowers response precision. Participants' similarity judgments got more variable with time pressure, plateauing at medium time pressure, with SDs being .13 (no time pressure) $< .17$ (weak) $< .19$ (medium) $= .18$ (strong), signs denote statistical significance in a linear mixed model. In turn, participants' mean similarity judgments for the stimulus pairs followed the same rank order across all experimental conditions. This strongly suggests that time pressure did not change participants' similarity judgments qualitatively, as would be expected from an attention focus or a simplified similarity. In sum, we found that cognitive load in similarity-based categorizations and judgments does not necessarily affect computational processes related to attention or psychological similarity, but rather the precision with which people translate their internal beliefs to manifest responses.

Coupled Hidden Markov models for Categorization

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Session:
Categorization

One intuition in the categorization literature is that how we assign a stimulus to a given category depends on the assignment of other stimuli that we have encountered in the past. In other words, it is assumed that stimulus–stimulus interactions can affect categorization decisions. Nevertheless, categorization models typically avoid modeling this feature by either considering the "true" category assignment for the stimulus, for a fixed experimental design, or by taking some function of a participants' previous responses. A consequence of these assumptions is that learning about the associations between a specific stimulus and the categories can only occur on trials when that stimulus is presented. Coupled Hidden Markov models (CHMM) allow stimulus-stimulus interactions in categorization to be modeled directly, so that association to categories are continuously updated The key idea under this approach is that the category (state) that a given stimulus (chain) is assigned to on a trial is a function of its assignment on the previous trial and the category that all other stimuli are inferred to be in. In other words, category assignments are updated continuously by a latent process based on participants' trial-by-trial choices. We present a Bayesian implementation of a CHMM on two classic categorization tasks: Lewandowsky's (2011) replication of the Shepard et al. (1961) Type VI category structures, and the extension of this task to ternary stimuli presented by Lee and Navarro (2002). We show that the CHHM model allows us to obtain posterior inferences about the category assignment (state) of each stimulus at every trial in the experiment.

Towards unifying category learning, probability learning and risky gambling using the CAL framework of rule and attention learning

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Session:
Categorization

Stimulus classification is an everyday feat (e.g., in medical diagnoses by differentiating ultrasound images). Category feedback, however, is often non-deterministic (e.g., by 25% chance untrue a.k.a. probabilistic feedback) rendering experiences as somewhat unreliable, and the question is how humans (still) learn stimulus-category regularities. In probability learning and economic decisions, such as risky gambles, however, the question usually reverses to why humans do not perfectly exploit regularities when correct categorization leads to reward (e.g., non-rational probability matching; Feher da Silva, et al., 2017; Plonsky, Teodorescu, & Erev, 2015). Here, we address both questions in a domain-general framework formalizing how humans, in probabilistic tasks, learn sequential feedback regularities in parallel to visual category structures. We use our recently introduced Category Abstraction Learning (CAL) framework (Schlegelmilch, Wills, & von Helversen, 2021), a connectionist category learning model able to extrapolate and contextually modulate simple rules. We implement the idea that participants count the streak of common events (stimulus) to predict when rare events or violations of a learned rule will occur (e.g., conditional hypotheses). We show that CAL's learning mechanisms readily extend to the mentioned domains, predicting probability matching in general based, but also the proportion of strategies often discussed as Win-Stay-Lose-Shift (WSLS), and more recently studied sequential pattern learning (akin to gamblers fallacy). CAL also provides an account of expectancy priors (see Koehler & James, 2014), proposing that they stem from an awareness that unobserved stimuli lead to unobserved outcomes (contrasting) which are continuously updated during experience-based decision making. We present CAL simulations and brief reanalyses of studies on risky gambles, probability learning and fear conditioning (e.g., Szollosi et al., 2022) showing CAL's potential to address long-standing questions regarding non-stationary expectations of stimulus-outcome probabilities and risk preference in terms of rule abstraction.

Human category inference is mostly independent of the distribution of features within categories

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Session:
Categorization

People habitually assign objects to categories based on the objects' features. In each category, the object features are distributed, meaning that they can vary and correlate across the category members. Past research has found mixed evidence concerning the extent to which people make use of the distribution of features in categories to categorize new objects. To investigate how within-category feature distributions affect people's categorizations, we collected and analyzed data from two categorization experiments. Participants classified geometrical figures with two features in a trial-by-trial supervised, binary category learning task, followed by an unsupervised transfer task with new feature value combinations. In both experiments, the experimental designs were optimized to compare categorization models that either consider or ignore within-category feature distributions. Experiment 1 used a high-variance category and a low-variance category, and the transfer stimuli fell between the categories. In Experiment 2, both categories had a strong feature correlation, and the transfer stimuli were located in the correlational direction of one category but closer to the members of the other category. Importantly, processing the within-category feature distributions affected how the transfer stimuli would be classified. Our results show that participants' classifications of the transfer stimuli were in line with ignoring the within-category feature distributions in both experiments. This means that participants (both $Ns = 43$) assigned the transfer stimuli predominantly to the low-variance category in Experiment 1 ($M = 71\%$) and to the closer category with an incongruent feature correlation in Experiment 2 ($M = 88\%$). Computational cognitive modeling showed that the model which ignores within-category feature distributions described most participants in both experiments with strong evidence ($n = 27$ in the variance experiment; $n = 32$ in the correlation experiment), suggesting that people mostly ignore the within-category feature distributions when they categorize new objects. One reason for these findings might be the computational costs involved in estimating the distribution of features in categories.

To simulate or not: the mechanistic underpinnings of predicting the decisions of other people

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Bavard, Sophie
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Gluth, Sebastian
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Session:
Evidence-Accumulation Models: Applications II

Sequential sampling models (SSM) assume that decisions for oneself are made by accumulating evidence for the available options, until the choice of one option has been triggered. As such, it seems plausible that predicting the decisions of another individual could be achieved similarly, by simulating the other person's evidence accumulation process with one's own cognitive mechanisms – the 'simulation hypothesis'. Although SSMs have been successfully used to describe predicted decisions of other agents, that in itself is insufficient evidence in support of the simulation hypothesis. However, one concrete implication of the hypothesis is that, if people use their own mind to simulate and predict the decisions of others, then biasing an individual's own decision-making process should result in a corresponding bias when they make predictions. To test this, we first biased participants' risk perception ($n = 172$) by adapting them to a high-risk/low-risk context when they made decisions for themselves, and subsequently asked them to predict the decisions of a risk-seeking and risk-averse (hypothetical) agent in a medium-risk context. On average, participants in the high-risk adaptation group predicted a more risk-accepting behaviour than those in the low-risk group, indicating that the predicted decisions were made with participants' own biased decision-making system - consistent with the simulation hypothesis. Surprisingly, this effect was only present during prediction for the risk-averse, but not risk-seeking agent, suggesting that the mechanisms of prediction may depend on the specific characteristics (e.g., similarity) of the other person. We also fit our data with a version of the drift diffusion model devised to account for risky decisions, to understand how the seemingly different mechanisms of prediction across agents are captured in the SSM framework.

Do not make decisions on an empty stomach: the impact of hunger state on attention and dietary choice processes

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Session:
Evidence-Accumulation Models: Applications II

Hunger is a biological drive, with the function of motivating a mechanism to eat to reach homeostasis. Hungry participants are particularly likely to choose hedonic food options. Here we apply a version of a sequential sampling model to elucidate the mechanisms underlying the hunger-driven impairment in healthy dietary choice. We implemented a binary food choice task, in which two food images (representing tastiness of the option) and their respective Nutri-Score (representing healthiness of the option) appeared on the screen. Participants completed the task in a hungry and a satiated state (within-subject design) while their eye-movements were being recorded. In line with our hypothesis, behavioral evidence demonstrated that participants were more likely to choose tasty over healthy food items, and this difference was amplified by hunger state.

To identify hunger-driven effects on decision processes, we used an extension of the Drift Diffusion Model, the multi attribute-time dependent Drift Diffusion Model (mtDDM) (Sullivan & Huettel, 2021, Nat Hum Behav), which allows the options' underlying attributes (here taste and health) to influence the decision process with different latencies and different weights. Applying the mtDDM to our data, we found that in both conditions' health latencies were significantly later than taste latencies and health weights were significantly lower than taste weights. When comparing conditions, there was no significant influence of hunger state on the attributes' latencies. However, we found that health weights were significantly reduced in the hungry compared to the sated condition, while taste weights were unaffected. This suggests that poor dietary choices under hunger are driven primarily by an impairment in health consideration in the decision process.

Notably, our modeling results also revealed that the mtDDM predicts that more than 20% of the estimated responses are made faster than the estimated latencies, that is, before any attribute information comes into play. While the purpose of the mtDDM is to predict multi-attribute choice, we would argue that it may not be suited for tasks in which the underlying attributes are represented distinctly. Further analyses of the eye-tracking data, combined with different implementations of dynamic process model of decision making will extend our understanding of the effects of hunger on attentional dynamics and preference formation in dietary decision making.

A discrete mixture decision field theory model for capturing preference and decision process heterogeneity in health choices.

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Session:
Evidence-Accumulation Models: Applications II

Discrete choice experiments in healthcare typically include only a small number of choice tasks for each participant to minimise the burden on responders. The complexity of healthcare issues means that choice tasks often include many attributes and/or alternatives. Consequently, individual-level models are not possible. Differences in behaviour, preferences, and decision-making processes must be captured with the use of more complex behavioural models. The inclusion of sociodemographic parameters in the model aids the detection of deterministic heterogeneity, while stochastic heterogeneity is typically captured using random parameters or latent class structures. However, neither of these methods are particularly well-suited to disentangling confounding sources of heterogeneity, that is, to detect individuals who make decisions in different ways separately from the identification of different preferences. In the current work, we address this issue using a discrete mixture model. This model estimates probabilities for each individual having particular tastes, and separately estimates probabilities of using different decision-making processes. In particular, we develop a discrete mixture decision field theory (DMDFT) model to capture preference heterogeneity through different attribute importance parameters whilst accommodating the different processing speeds of decision-makers and propensities to be subject to the similarity effect through different process parameters. We apply the model to datasets from discrete choice experiments on tobacco preferences. We demonstrate that (a) DMDFT models outperform latent class DFTs, providing clearer insights on individual differences (b) the models outperform their counterpart econometric choice models, and (c) the models find clear differences in the individuals' decision-making processes as well as preferences.

Understanding the dynamics of serial dietary decisions through the lens of sequential sampling modeling

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Session:
Evidence-Accumulation Models: Applications II

Often in our lives, we need to take a series of sequential actions rather than making a single, isolated decision. A typical everyday example is to decide which and how many items we want to put in our shopping basket. Multiple previous studies have investigated the temporal dynamics of these sequential decisions using a virtual shopping paradigm (Wolf et al., 2018, 2019; Xu et al., in press). Specifically, these studies have examined the probability and speed of dietary decisions with various constraints but did not further study the underlying cognitive mechanisms. Here, we show how a process model based on the sequential sampling modeling framework can elucidate those mechanisms and provide a comprehensive account of the reported choice and response time (RT) patterns. In the virtual shopping paradigm, participants decided for sequentially encountered items whether or not to add them into their shopping basket ("pick" or "leave"). The number of food items that could be added to the basket was limited and manipulated in one experiment. In some conditions, participants were given the opportunity to defer the food item by placing it on a waiting list. Importantly, "pick" decisions tended to be longer than "leave" decisions, and this difference was most pronounced when fewer food items could be selected. Decisions to wait were slower than both "pick" and "leave" decisions. On the inter-individual level, the RT difference between "pick" and "leave" decisions was higher for participants who rejected more options. We account for these choice and RT patterns using a new variant of the Feed-Forward Inhibition model (FFI) (Shadlen & Newsome, 2001) with three separate accumulators for the decisions "leave", "pick", and "wait". The "leave" and "pick" accumulators, but not the "wait" accumulator, inhibit each other. Due to the limited basket space, we assume that participants have a default preference for leaving the food item, which we implement by shifting the starting point of the accumulation process in favor of "leave" vs. "pick" decisions as a function of the basket size. Our simulations show that this model can account for the various choice and RT patterns in the virtual shopping paradigm, including the RT difference in "leave" vs. "pick" decisions, the excessively long "wait" decisions, and the dependency of these differences on the basket size. In addition, when inspecting our simulations, we see that the drift rate of "pick"-choices is considerably higher than average, mimicking the fact that only high-value food items are chosen for the basket. In contrast, the drift rate of "wait"-choices is only slightly above average, suggesting that food items which are of a somewhat higher value are put on the waiting list.

Drift diffusion model-informed EEG and dynamical systems to uncover the mechanisms of depressive thinking and decision making

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Session:
Evidence-Accumulation Models: Applications II

Major depressive disorder is characterized by among others difficulty in letting go of negative and self-deprecating thoughts. To allow for a deeper mechanistic understanding of rumination and depression more generally, cognitive tasks and computational modeling play a major role. We have shown that thinking that is difficult to disengage from, such as rumination, can be captured in tasks that track spontaneous thinking. In fact, we demonstrated that this sticky thinking is associated with increased alpha oscillatory power. Moreover, using alpha power in the drift diffusion model shows that high alpha is associated with a lower drift rate, suggesting that sticky thinking disrupts the decision making process. Using a very different kind of modeling, a dynamical systems analysis shows that sticky and self-related thinking is more difficult to control.

One does not simply correct for serial dependence

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Session:
Statistical Methods

Serial dependence is present in most time series data sets collected in psychological research. This paper investigates the implications of various approaches for handling such serial dependence, when one is interested in the linear effect of a time-varying covariate on the time-varying criterion. Specifically, the serial dependence is either neglected, corrected for by specifying autocorrelated residuals, or modeled by including a lagged version of the criterion as an additional predictor. Using both empirical and simulated data, we showcase that the obtained results depend considerably on which approach is selected. We discuss how these differences can be explained by understanding the restrictions imposed under the various approaches. Based on the insight that all three approaches are restricted versions of an autoregressive distributed lag model, we demonstrate that accessible statistical tools, such as information criteria and likelihood ratio tests can be used to justify a chosen approach empirically.

Sequential ANOVA: An Efficient Alternative to Fixed Sample Designs

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Session:
Statistical Methods

The replication crisis has shown that researchers often collect insufficient sample sizes for their studies or use questionable research practices such as data peeking. Sequential testing procedures are one possible solution to these shortcomings. The Sequential Probability Ratio Tests (SPRTs) offer interesting possibilities within Frequentist Statistics. Here, a likelihood ratio is calculated as a test statistic, which can be computed continuously by adding new data points. After each iterative step of data collection, SPRTs decide whether the evidence is sufficient to accept the null or alternative hypothesis or whether more data points are needed. SPRTs control for alpha and beta error rates and require, as a test specification, a minimum expected effect size. We show in simulation studies that the one-way sequential ANOVA is very efficient compared to a classical fixed ANOVA. In 87% of the simulated cases, the sequential samples are smaller than the fixed samples. On average, 56% of the data can be saved using the sequential design. However, sequential designs show biases in effect size estimation. Thus, we want to discuss the benefits and limitations of sequential testing. The R package sprtt can be used to calculate sequential versions of t-tests and one-way ANOVAs.

Assessing goodness-of-fit of the queueing model of visual search to accuracy data

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Session:
Statistical Methods

The queueing model of visual search proposed by Li, Schlather, and Erdfelder (in press) is a novel mathematical model that accounts for both accuracy and response time in standard visual search with interpretable parameters. One of the merits of the model is that the probabilities of correct and incorrect responses are specified as analytical functions of the experimental manipulations, namely the set size (i.e., the number of stimuli in the display) and the presence or absence of the target. As a result, the number of model parameters remains constant even if the number of set size levels increases. However, its ability to incorporate quantitative features of the experimental condition comes with the cost that tailor-made goodness of fit tests need to be developed. The application of a standard likelihood ratio test provides too conservative results because the model implies more restrictive patterns than its number of free parameters suggests. In this presentation, I show that the distribution of the commonly used likelihood ratio statistic under the null hypothesis cannot be approximated asymptotically by the chi-square distribution with degrees of freedom that equal the difference in the number of free parameters. I explain the reasons in detail and compare alternative goodness-of-fit measures based on various approaches.

Towards a formal approach for (negative) Delta-Plots

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Session:
Statistical Methods

Delta-Plots (DPs) are valuable for analyzing reaction time (RT) experiments. They help to differentiate between various cognitive models and theories and to identify different mechanisms behind observed effects, such as the Simon or Stroop effect.
The conventional definition of DPs is based on empirical data (empirical DPs; e.g. Schwarz & Miller, 2012), which contrasts with other statistical definitions relying on population distributions or estimators of population properties. Moreover, the details of the estimation procedure, e.g. the number of bins, can affect the properties of the estimates. While a definition using population distributions exists (distributional DPs; Speckman et al., 2008), it is less common. Nevertheless, we show that the distributional definition in combination with psychological models poses some interesting implications regarding, e.g., the monotonicity of DPs. Unfortunately, it is unclear how these two definitions relate formally, e.g. if empirical DPs can be considered an estimator of distributional DPs. Furthermore, both definitions only concern individual DPs for single participants, but it is open how population DPs should be defined. Consequently, the concept of a DP for a specific task, such as the Simon or Stroop task, is not well-defined.
To address some of these issues, we present an algorithm that uses kernel-density estimations of the cumulative density function (CDF) to estimate DPs. Our algorithm leverages the Newton-Raphson method to enable the computation of the empirical DPs at arbitrary RTs. By using a direct estimation of the CDF, our method is closer to the formal definition of DPs based on population distributions and allows for the computation of DPs at any RT. Hence, it offers new ways to generalize individual DPs to population DPs.
We also discuss open questions regarding negative DPs (nDPs) for population distributions and propose possible definitions of nDPs that address these questions.

Navigating cognitive parameter space

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Session:
Statistical Methods

In fitting computational models to data, we represent the data (e.g. reaction time distributions) in terms of a small set of psychologically meaningful latent dimensions (e.g. parameters in an evidence accumulation model). Fitting a model to observed data then involves finding a point in this "cognitive parameter space" that is likely to have generated the data. Typically that is where the mechanistic explanation ends and we do not specify or, indeed, ask how an agent ended up at that point. The (often implicit) assumption is that agents try to maximise some objective function through some optimisation process (e.g. gradient descent). However, we rarely take the agent's perspective and consider the information and cognitive mechanisms available to conduct their search through the parameter space. This search is subject to several constraints. Sampling the objective is necessarily serial, local and time-consuming: objective estimates at a given location are likely to be uncertain and the agent may need several interactions with the environment to reduce this uncertainty. In light of these constraints, we explore a cognitively more plausible (i.e. minimal) search strategy. This strategy is based on local sampling of an objective function and making ordinal comparisons with only the most recently visited location in the parameter space. We report simulation results for the behaviour of this algorithm for optimising and satisficing agents, under a range of boundary conditions (e.g. noise in the objective estimates and the granularity with which objective comparisons can be made). Our overall argument is that identifying the information and mechanisms available to agents for navigating the cognitive parameter space is critical for understanding variation in cognition and behaviour over time, between different environmental conditions and between different populations or individuals.

Measurement of memory

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Anderson, Laura

Session:
Memory

For over 70 years, recognition memory has been modelled using signal detection theory. An unsolved problem with this approach is that the shapes of the distributions of memory strength for studied and unstudied items are unknown. Although they are often assumed to be Gaussian, with different location and scale parameters, such models often fail to fit observed data. This has had the effect of sustaining the viability of alternative approaches such as discrete state models, mixture models, and hybrid dual process models. However, it is now possible to estimate the shapes of the proposed memory strength distributions using the monotonic linear regression algorithm developed by Dunn and Anderson (under review). We describe this algorithm, show how it can recover the relevant distribution shapes under the signal detection model, and show that it fails to do so under alternative models. We apply it to data from three item recognition experiments. Each experiment used the same set of stimuli and varied the number of study presentations (1, 2, or 4) and the nature of the study item or the study task: visual vs. auditory presentation (Experiment 1), read vs. generate task (Experiment 2), and focused vs. divided attention task (Experiment 3). While the results confirm the predictions of the signal detection model, the recovered distributions deviate from the Gaussian. Furthermore, we show that the regression weight associated with each condition can be interpreted as a measure of memory strength for that condition, replacing traditional indices such as d-prime.

ROC Asymmetry and the Target-Probe Invariance Assumption in Recognition Memory

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Session:
Memory

When modeling recognition-memory judgments, it is typically assumed that requesting participants to judge whether a given test item is 'old' is mnemonically equivalent to asking whether that very same item is 'new'—an assumption denoted as target-probe invariance. Contrary to this notion, results we recently obtained by means of a detection-plus-identification tasks (Meyer-Grant & Klauer, 2023, Memory & Cognition) seem to suggest that the mnemonic information available to a decision maker in fact changes depending on the status of the target being probed (i.e., that target-probe invariance is actually violated). For example, one of the key observations was an impairment of identification performance when new items instead of old items were defined as targets to be detected and identified. As a side-effect of this finding, an important earlier test of receiver operating characteristic (ROC) asymmetry may be questioned inasmuch as a violation of target-probe invariance provides an alternative interpretation of effects observed with this test. Interestingly, however, assuming a contamination of identification responses with occasional guessing in trials where no target is detected allows one to account for the observed difference in identification performance while retaining the target-probe invariance assumption. To enable a more conclusive resolution of this issue, we conducted further analyses of our previously published data and a new experiment that comprised no target-absent trials. Overall, the results indicate that identification responses in our original study may indeed have been contaminated by occasional guessing, thus rehabilitating the target-probe invariance assumption as well as the previous test of ROC asymmetry. This highlights the importance of carefully considering the experiment model in addition to the theoretical model when conducting critical tests that are motivated by mathematical models of cognitive processes.

Improving Memory Search through Model-Based Cue Selection

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Session:
Memory

We often use cues from our environment when we get stuck searching our memories, but prior research in memory search has not observed a facilitative effect when providing cues after recall ended. What accounts for this discrepancy? We propose that the content of the cues critically determines their effectiveness and sought to select the right cues by building a computational model of how memory search is affected by cue presentation (in a process we refer to as cued memory search). We hypothesize that cued memory search consists of (1) a basic memory search process, identical to memory search without external cues as captured by the existing Context Maintenance and Retrieval model (CMR), and (2) an additional process in which a cue's context influences one's internal mental context. Formulated this way, our model (with parameters pre-determined from a group of participants) was able to predict in real-time (over a new group of participants) which cues would improve memory search performance. Participants ($N = 195$ young adults) recalled significantly more items on trials where our model's best (vs. worst) cue was presented. Our formal model of cued memory search provides an account of why some cues are better at aiding recall: Effective cues are those most similar to the remaining items, as they facilitate recall by tapping into and reactivating an unsearched area of memory. We discuss our contributions in relation to prominent theories about the effect of external cues.

Retrieving dynamically and effectively from memory (D-REM): A recognition memory model with dynamic decision making mechanism

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Session:
Memory

The recognition memory models explain the processes of representation, encoding, and retrieval of items, and make performance predictions. These models are mostly based on the basic stages of familiarity calculation for a probe and a recognition decision based on a threshold value for endorsement of the probe. However, the course of decision making during recognition has been widely ignored in the recognition modeling literature. The research has mostly focused on explaining accuracy data but ignored the response time (RT) findings until the advent of dynamic recognition memory models (e.g. Cox & Shiffrin, 2012, 2017; Diller et al., 2001; Malmberg, 2008; Hockley & Murdock, 1987; Osth, Jansson, Dennis, & Heathcote, 2018). In recent years, dynamic recognition modeling research achieved promising results to account for the major findings on RT data. In the current study, we have been developing a novel dynamic version of Retrieving Effectively from Memory (REM, Shiffrin & Steyvers, 1997), which is one of the major recognition models. The model, called Retrieving Dynamically and Effectively from Memory (D-REM), incorporates the representation, encoding and likelihood calculation mechanisms of REM while including a dynamic decision making process based on sequential sampling. D-REM assumes that items are represented as vectors of item features. According to REM, encoding is a stochastic process with errors. Retrieval is made by comparisons between the test item and the memory traces, and the recognition decision is made by the likelihood calculation based on these comparisons. During retrieval, the features of the memory traces gradually enter into the buffer system in which the likelihood calculations are made. Thus, the evidence as to whether the probe is old or new accumulates in time towards the decision boundaries. The accumulation of evidence continues until it reaches one of the "yes" or "no" decision boundaries. The memory is updated according to the recognition decision. With this mechanism, D-REM proposes a novel account for the course of decision making during recognition. Including a time-varying boundary mechanism and a starting point parameter, the model aims to be the most extensive dynamic model in the REM framework. Examination of alternative variants of the model with differing drift rate and boundary mechanisms will provide further evidence on the time-course of evidence accumulation and response caution during a decision. We will present the simulations for standard yes-no recognition task and recognition with response deadline procedure via the preliminary variants of D-REM model. The model will be revised and improved according to the comparisons between alternative variants.

Order-Constrained Models of Memory

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Session:
Memory

Hypotheses in free recall experiments often predict a greater average recall for one type of stimuli compared to another type. A frequent assumption – often implicit in statistical tests of these hypotheses – is that item recall is normally distributed. However, this assumption can be problematic in the domain of memory. Additionally, common statistical testing methods for testing theories can be blunt instruments. Researchers may be interested in more nuanced hypotheses that are cumbersome to test with traditional methods. For example, ideal theories might even make granular predictions about the memorability of each studied item, including that certain individual items are equally memorable. Here, we propose order-constrained models for recall data as a fruitful method of analysis that allows researchers to formulate, and test, nuanced and fine-grained hypotheses about recall. We illustrate the benefits of order-constrained modeling by re-analyzing data from a pre-registered experiment on the memorability of supernatural, bizarre, and natural concepts. We formulate and test a series of plausible and nuanced hypotheses. Order-constrained inference reveals differences in evidential support between different possible mathematical formulations of a single verbal theory.

Type I error rates for ANOVA, GLM, and GLMM for binary outcomes when simulating from binomial logistic model and Ratcliff diffusion model

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Session:
Posters: Statistics and Bayesian Models

Logistic regression models are often recommended for analysing binary response variables, such as accuracy, that commonly arise in psychological research designs. One of the main reasons for this recommendation are simulation studies showing that binomial logistic models outperform ordinary ANOVA models when simulating from a binomial logistic model. However, such a simulation setup is at risk of circularity as the logistic model is both the data generating and winning candidate model. To overcome this limitation, we compared different candidate models when simulating from two data generating models – a binomial logistic model and the Ratcliff diffusion model. For each simulation study, we simulated a two-group between-participants design with 30 participants per condition. We also varied the number of observations per simulated participant, either 1 observation or 100 observations. We then compared the type I error rates (i.e., the proportion of false positive errors) from three popular candidate methods, linear regression (ANOVA), generalised binomial logistic regression (GLM), and generalised binomial logistic mixed models (GLMM).

Our results suggested that ANOVA shows the best performance in terms of type I errors across different simulation setups and data generated by both logistic and diffusion models. For the GLM, the type I error rate was around 0.05 only for 1 observation per participant and severely anti-conservative (i.e., too high type I error) for 100 observations. GLMM yielded an acceptable type I error rate with 100 observations per participant but varied amounts of type I errors dependent on the data generation models with 1 observation per participant. When simulating from the logistic model GLMM produced acceptable type I error rates but too high type I error rates when simulating from the diffusion model. Additionally, the type I errors from GLMM with 1 observation per participant increased as the overall performance level approached the boundary of the parameter space. Overall, our results suggest that in terms of type I error rates, ANOVA generally perform better than logistic models in most cases and the performance of logistic models depend exactly on the simulation setup.

Contiguity Effect Is Asymmetric Across Pairs, How About Within?

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Session:
Posters: Statistics and Bayesian Models

In the memory literature, paired associates and list recall have been studied separately. Recall probabilities of forward and backward recalls have been found approximately equal in paired associates. Whereas in free recall, subjects tend to successively recall words studied in nearby positions, denoted as the contiguity effect, favoring the following word over the preceding one. Temporal Context Model (TCM) proposes that items studied in nearby positions have similar study contexts and recalling an item activates its context along with its neighbors' which results in the contiguity effect and forward asymmetry. Kılıç et. al. (2013) developed a probed recall task to test the contiguity effect by interrupting the linearity of the experimental procedure. In the current study, we employed their probed recall task on the paired associates where participants studied multiple lists of pairs. At test, they were given a pair to recognize and required to go back to the list that the member was presented in and recall another word from the list. Conditional response probability (CRP) curves indicated both within and between list contiguity with the forward asymmetry, however a symmetric retrieval was observed in paired associates. These two patterns of recall data from the probed recall task are in line with the previous findings in the literature of paired associates and list recall patterns which fits the contextual coding mechanism of TCM.

Estimating multilevel signal detection theory models using maximum likelihood

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Session:
Posters: Statistics and Bayesian Models

Signal detection theory (SDT) is one of the most influential modeling frameworks in psychological research. One of its main contributions is the possibility to disentangle two central components in decisions under uncertainty: sensitivity, the ability to differentiate between signal and noise, and response bias, a tendency to favor one decision over the other. When applying such models to common psychological data comprising multiple trials of multiple participants, multilevel modeling is considered the state-of-the-art in psychological research. While the estimation of non-linear multilevel models such as SDT models is usually done in a Bayesian framework, this is not necessary to benefit from the advantages of this modeling approach: Multilevel SDT models can, in principle, also be fitted using maximum likelihood (ML) – although this is rarely done in practice, presumably due to the lack of appropriate software for doing so. We present our work on an R package that is aimed at supporting the straightforward application of this approach for researchers applying SDT. To fit multilevel SDT models using ML, we exploit the equivalence of SDT models and a subclass of generalized linear models (GLMs; DeCarlo, 1998). GLMs can easily be extended to multilevel models by including random effects in the model, yielding generalized linear mixed models (GLMMs). Thereby, multilevel SDT models can be fitted with ML by using commonly-known software packages for fitting GLMMs. Our R package allows one to fit different variants of multilevel SDT models with sensitivity and response bias parameters that can vary according to user-specified predictor variables and different sources of random variation. It "translates" the given SDT model to a GLMM, selects an appropriate random-effects structure, estimates the parameters, and transforms the parameter estimates for both population and subject level back to the SDT framework. In addition, likelihood ratio tests for given predictors can be calculated. We demonstrate the validity of our implementation through simulation studies.

Cross-modal matching and internal references

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Session:
Posters: Statistics and Bayesian Models

'Make the light as bright as the sound is loud.' This is a typical instruction in experiments dealing with the cross-modal matching of stimuli. According to Luce's (Luce, Steingrimsson, & Narens, 2010) theory of global psychophysics, in such a cross-modal task the perceived stimulus intensities are judged against respondent-generated internal reference intensities, all represented on a common psychological scale. Heller (2021) generalizes Luce's theory by distinguishing the internal references with respect to their role in the experimental setup, that is, whether they pertain to the standard or to the variable stimulus in the matching task.
By testing Heller's generalization of Luce's theory of global psychophysics on cross-modal data, the present study aims at thoroughly investigating the role-sensitivity of the internal reference intensities. For achieving this, it replicates a classical experiment by Stevens and Marks (1965), who made participants adjust the brightness of a light to the perceived loudness of a noise sound and vice versa. This allows for complementing the traditional group-level analysis by evaluating the data at the individual level, and for fitting the global psychophysical model to the data in a cognitive modeling approach. We find that on the individual level, the cross-modal matching curves differ in slope, and show a regression effect as reported in the classical literature. This implies role-dependent reference intensities as suggested by Heller's model. In order to experimentally manipulate the internal references' role-(in)dependence, an alternative psychophysical method is discussed. Using an adaptive staircase procedure within the method of constant stimuli, and if instructed to choose the more intense stimulus, the subject is not aware which of the stimuli is the standard and which the variable stimulus. Under these conditions the internal references are expected to be role-independent, and the regression effect should vanish.

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Luce, R. D., Steingrimsson, R., & Narens, L. (2010). Are psychophysical scales of intensities the same or different when stimuli vary on other dimensions? Theory with experiments varying loudness and pitch. Psychological Review, 117(4), 1247–1258. https://doi.org/10.1037/a0020174
Stevens, J. C., & Marks, L. E. (1965). Cross-modality matching of brightness and loudness. Proceedings of the National Academy of Sciences of the United States of America, 54(2), 407.

Quantitatively fitting the Autocorrelated Bayesian Sampler to accuracy and response time data

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Session:
Posters: Statistics and Bayesian Models

The Autocorrelated Bayesian Sampler (ABS, Zhu et al., 2021) is a sequential sampling model that assumes people draw autocorrelated samples from memory of hypotheses according to their posterior beliefs, producing choices, response times, confidence judgments, estimates, confidence intervals, and probability judgments. Decisional evidence accumulation times are exponentially distributed and samples are aggregated until those in favour of one response category exceed those in favour of the other, then the favoured option is chosen. While this mechanism qualitatively accounts for a range of effects of accuracy and response time (e.g., fast and slow errors), it has never been quantitively evaluated. Therefore, we compared the ABS 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. We fit both models to the data from Murphy et al.'s (2014) research, a random dot motion task, using a Bayesian form of quantile maximum likelihood (Heathcote et al., 2002) to evaluate how well the models account for the data. Comparing the two models will illustrate how differences in their assumptions and approaches affect their performance in different scenarios, and point to what is necessary to make the ABS competitive with the best models of accuracy and response times.

Markov-switching models enable precise recovery of cognitive events from trial-level pupil dilation time courses

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Session:
Posters: Statistics and Bayesian Models

Pupil dilation time courses are assumed to be a slow and indirect reflection of the latent cognitive events involved in task performance. Additive models of pupil dilation can be used to recover these events through deconvolution, promising a more precise study of cognitive processes. To this end, the conventional deconvolution method assumes that cognitive events all trigger a delayed pupil response. The weighted sum of these individual responses is then believed to be reflected in the pupil dilation time course.
Importantly, the conventional method typically assumes the same shape for the pupil responses elicited by all events. Additionally, the method is usually applied to averaged time courses. Thus, it neglects the possibility that the timing between events and the shape of the response differs not just between subjects but also between trials and even different cognitive events. However, accounting for trial and event-level variability is crucial to achieve precise recovery of latent events and thereby a detailed understanding of cognitive processing. Moreover, accounting for trial-level variability is necessary when investigating how trial-level predictors (e.g., continuous word frequency) influence cognitive processes involved in task performance.
To ensure a precise recovery of latent cognitive events, we propose an extended model that combines generalized additive mixed models with Hidden semi-Markov models. We will show that despite the added complexity the model recovers parameters accurately and that the risk of overfitting is minimized through efficient and automatic regularization. Finally, we will apply this model to data from a lexical decision experiment in which participants processed words and two types of non-words which differed in their frequency (approximated with Google result counts), to investigate the cognitive events involved in lexical decisions and how they are affected by word type and frequency manipulations.

Bayesian-frequentist p-values: The best of both worlds

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Session:
Posters: Statistics and Bayesian Models

Currently, researchers need to choose between one of two different statistical frameworks, a frequentist or Bayesian approach. Frequentist inference – null hypothesis significance testing – is the de-facto standard. It is computationally relatively cheap and comparatively convenient as it does not require the researcher to specify a prior on the effect to be tested. Bayesian inference is becoming increasingly popular, in large parts due to easy-to-use software such as brms that make it easy to estimate complex models with little programming. In contrast, where Bayesian estimation is convenient even for quite complex models, Bayesian testing via Bayes factors is computationally expensive and rather cumbersome as it requires the specification of a prior that can largely influence results. We evaluate a compromised approach that combines Bayesian estimation with frequentist testing: Bayesian-frequentist p-values, where Bayesian model estimation is combined with frequentist Wald-based p-values. To assess this combination, we examine the type I error rates of Bayesian-frequentist p-values across three different settings: regular analysis of variance (ANOVA), logistic regression, and logistic mixed-model designs. Our results showed that Bayesian models with improper flat priors produced nominal type I error rates mirroring the behaviour of frequentist models across all designs. However, non-zero-centred priors resulted in too high (i.e., anti-conservative) rates of type I errors and zero-centred models produced low (i.e., conservative) rates of type I error, with the degree of conservativity depending on the width of the prior. Overall, our results indicate that frequentist testing can be combined with Bayesian estimation if the prior is relatively non-informative. Bayesian-frequentist p-values offer an attractive alternative to researchers, combining the ease of frequentist testing with the convenience and flexibility of Bayesian estimation.

On the consistency and relative efficiency of a generalized Robbins-Monro process for threshold estimation

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Session:
Posters: Decision Making and Evidence-Accumulation Models

In classical psychophysics, the study of threshold and underlying representations is of theoretical interest, and the relevant issue of finding the stimulus (intensity) corresponding to a certain threshold level is an important topic. In the literature, researchers have developed various adaptive (also known as 'up-down') methods, including the fixed step-size and variable step-size methods, for the estimation of threshold. A common feature of this family of methods is that the stimulus to be assigned to the current trial depends upon the participant's response in the previous trial(s), and very often a Yes-No response format is adopted. A well-known earlier work of the variable step-size adaptive methods is the Robbins-Monro process. However, previous studies have paid little attention to other facets of response variables (in addition to the Yes-No response variable) that could be embedded in the Robbins-Monro process. This study concerns a generalization of the Robbins-Monro process by incorporating other response variables, such as response confidence, into the process. We first prove the consistency of the generalized method and explore possible requirements, under which the proposed method achieves (at least) the same efficiency as the original method does. We then conduct a Monte Carlo simulation study to explore some finite-sample properties of the estimator obtained from the generalized method, and compare its performance with the original method.

Can self-generated choice options result in reduced choice satisfaction?

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Session:
Posters: Decision Making and Evidence-Accumulation Models

Making decisions often requires generating a list of candidate choices from memory and considering the value of the generated candidates before making a decision. That posits a dilemma: at which point should we stop generating candidates and choose from the current options? Models of multiattribute choice suggest that more extended evidence accumulation will result in less noisy evidence, and, as a result, the value assigned to candidate choices should more closely resemble one's true preferences. This account would predict that longer intervals of generating candidate choices should result in higher satisfaction with one's choices. However, research in consumer Psychology has highlighted that, in many cases, having access to more options can be detrimental for choice satisfaction (Scheibehenne et al., 2006). Therefore, it is plausible that considering more candidates when generating potential choices can result in lower choice satisfaction. Here, we perform the first systematic analysis of choice candidate generation and resulting choice satisfaction. We first investigate the relationship between the number of candidates produced before deciding on the resulting choice satisfaction, expecting that people who list more options end up less satisfied with their choice. In a second experiment, we will further explore this effect by manipulating the number of candidate options participants generate before deciding. Finally, we will extend current models of choice (Bhatia et al., 2021) to build a model that can produce diminished choice satisfaction with larger numbers of candidate options. Our approach rests on the idea that longer consideration duration increases the likelihood of more heterogenous candidates, making comparing and evaluating these candidates more complex. Our approach combines current models of memory search with decision-making and choice satisfaction allowing us to shed light on the processes that govern everyday decision-making.

Towards utilizing evidence accumulation models in applied settings – using informative prior distributions to decrease sample size demands

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Session:
Posters: Decision Making and Evidence-Accumulation Models

A hurdle preventing Evidence Accumulation Models (EAMs) from wide utilization in applied settings, where individuals cannot (or will not) provide many repeated decisions, is their sample size demands. In this project, we investigated whether Bayesian hierarchical modeling approaches offer a solution: We hypothesized that informative prior distributions decrease these sample size demands to numbers that are obtainable in practice. Through a simulation study and a reanalysis of experimental data, we explored the lower limit on the sample size to still reliably estimate individual participants' data-generating parameters.
In the simulation study, we first compared the effects of various sample sizes and types of prior distributions (uninformative prior; informative and accurate prior; informative but inaccurate prior) on the estimation of parameters for Diffusion Decision Models (DDMs), a class of EAMs. Results revealed that several DDM parameters can be recovered with sample sizes as small as 10, if the prior is correct and informative. However, especially for very small sample sizes, the type of prior distribution was critically important. Subsequently, we assessed the effect of sample size on parameter recovery under more realistic circumstances by reanalyzing data from a driving experiment. We tested how well parameters can be recovered based only on a few observations from a single participant if data of the remaining participants provide informative prior distributions. For most assessed DDM parameters (drift rate, boundary separation, and bias, but not non-decision time), we achieved satisfactory levels of parameter recovery with 20 observations. Additionally, we confirmed that we meaningfully updated the prior distributions towards the ground truth by including these 20 observations.
This work opens the door for reliable estimation of decision-making processes under real-life circumstances (e.g., when individuals cannot provide many repeated decisions; or when we are interested in real-time estimation of parameter fluctuations to monitor changes in people's mental states).

The Effects of Non-Diagnostic Information on Confidence and Decision Making.

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Session:
Posters: Decision Making and Evidence-Accumulation Models

Many decision-making tasks are characterized by a combination of diagnostic and non-diagnostic information, yet models of responding and confidence almost exclusively focus on the contribution of diagnostic information (e.g., evidence associated with stimulus discriminability), largely ignoring the contribution of non-diagnostic information. An exception, Baranski and Petrusic's (1998) doubt-scaling model, predicts a negative relationship between non-diagnostic information and confidence, and between non-diagnostic information and accuracy. In two perceptual-choice tasks, we tested the effects of manipulating non-diagnostic information on confidence, accuracy, and reaction time (RT).
In Experiment 1 (N=56), participants viewed a dynamic grid consisting of flashing blue, orange and white pixels and indicated whether the stimulus was predominantly blue or orange (using a response scale ranging from low confidence blue to high confidence orange), with the white pixels constituting non-diagnostic information. Increasing non-diagnostic information reduced both confidence and accuracy, generally slowed RTs, and led to an increase in the speed of errors. Experiment 2 ($N = 20$) was a near exact replication of Experiment 1, however this time participants were not asked to provide a confidence rating. This was to determine whether asking participants to make a decision and provide a confidence rating simultaneously influenced choosing behaviour. Like the first experiment, Experiment 2 found that increasing non-diagnostic information reduced both accuracy and generally slowed RTs (with an increase in the speed of errors), providing further support for the doubt-scaling model of confidence.

Exploring the Feasibility of Across-Trial Variability in Boundary Separation

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Session:
Posters: Decision Making and Evidence-Accumulation Models

The Diffusion Decision Model (DDM) is an effective tool for studying human decision-making across various domains (Krajbich, 2019; Ratcliff et al., 2016). In practice, including across-trial variability parameters allows the model to account for a variety of behavioral patterns, including fast errors, slow errors, and crossover effects (Ratcliff & Rouder, 1998; Ratcliff & Tuerlinckx, 2002; Van Zandt & Ratcliff, 1995). In this study, we are interested in using the DDM to fit data from many participants but with few observations per participant. By doing so, the across-trial variability parameters in the original model then become across-trial participant parameters. Though typically, across-trial variability has been estimated for the drift rate (sv), starting point (sz), and non-decision time (st) parameters (Boehm et al., 2018; Ratcliff & Childers, 2015; Ratcliff & Tuerlinckx, 2002). However, we know different participants have different boundary separation parameter values. To account for that, we modify the DDM to include across-trial variability in boundary separation (sa). Through simulation, we demonstrate that across-trial variability in boundary separation can produce distinct patterns, including fast errors, a reduction in the fastest response quantiles, and an increase in the slowest response quantiles. We next demonstrate the parameter's identifiability by successfully recovering across-trial variability in boundary separation for an extensive set of parameters. Ultimately, this study provides initial support for the feasibility of using across-trial variability in boundary separation to examine group-level parameters using a few observations per participant.

Comparing Amortized to MCMC-based Bayesian Inference for Cognitive Models of the Stop-Signal Paradigm

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Session:
Posters: Decision Making and Evidence-Accumulation Models

Amortized Bayesian Inference (ABI) is an emerging technique that improves on the ideas of approximate Bayesian computation by integrating non-parametric model learning via deep learning, only requiring a data-generative model.
This makes it a promising approach for cognitive modelling where more complex models often lack algebraic solutions to enable standard Markov-chain Monte Carlo (MCMC) approaches to parameter estimation. However, while simulation studies show promising convergence for cognitive models with ABI, it is not clear which conditions are needed to ensure its usefulness. Furthermore, it is often not clear if marginal and joint posterior estimates are true reflections of Bayesian inference for complex statistical models.
The presented research investigates how ABI compares to MCMC-based methods in the context of cognitive models of the stop-signal paradigm. Specifically, we investigated convergence and computational effort in ABI as implemented by BayesFlow (Radev et al., 2020) compared to the MCMC-based BEESTS as implemented by the DMC R package functions (Matzke et al., 2013; Heathcote et al., 2019).
We present numerical comparisons for and draw conclusions and take-aways for the application of ABI for (ExGaussian) models for stop-signal detection tasks.

Quantum Zeno effect in decision-making: time delay and no information about previous responses reduce coherence

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Session:
Posters: Decision Making and Evidence-Accumulation Models

The quantum cognition approach employs the mathematics of quantum theory to develop models of cognition and decision making. This theory predicts the quantum Zeno effect: when the state of a system is observed continuously, the evolution of state slows down because the quantum state is less likely to change if measures are taken within brief intervals. In the quantum cognition framework, the state vector represents the current cognitive state. When a judgement is made the vector collapses onto the corresponding axis. Over time, the vector oscillates moving away from the axis. By asking the same question multiple times, it is observed that the shorter the interval, the nearer the state vector will be to the axis. This implies a higher probability of giving the same response, resulting in a high coherence of judgement. We tested this prediction with two scenarios describing a hypothetical person and asking for a judgement about him/her. We gave two clues about the characteristic of this individual at once for three times. A total of 3241 participants completed the task, online and in person. We manipulated the time interval between each judgment (immediate vs 30 minutes), the availability of the previous responses given by each participant and the social desirability of showing coherence. In both scenarios, we observed an interaction effect between the time interval and the availability of information about previous responses. The coherence was reduced in the case of 30 minutes interval only if information was not available compared to the other conditions. Results are discussed in the light of the comparison between the quantum cognition framework and the classical approach as well as the cognitive processing underlying the coherence of judgements.

The role of task-relevant and task-irrelevant information in congruency sequence effects: Applying the diffusion model for conflict tasks

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Session:
Posters: Decision Making and Evidence-Accumulation Models

In conflict tasks, such as the Simon, Eriksen flanker, or Stroop task, the congruency effect is often reduced after an incongruent compared to a congruent trial: the congruency sequence effect (CSE). It was suggested that the CSE may reflect increased processing of task-relevant information and/or suppression of task-irrelevant information after experiencing an incongruent relative to a congruent trial. In the present study, we contribute to this discussion by applying the Diffusion Model for Conflict tasks (DMC) framework in the context of CSEs to flanker and Simon tasks. We argue that DMC independently models the task-relevant and task-irrelevant information and thus is a first good candidate for disentangling their unique contributions. As a first approach, we fitted DMC conjointly or separately to previously congruent or incongruent trials, using four empirical flanker and two Simon data sets. For the flanker task, we fitted the classical DMC version. For the Simon task, we fitted a generalized DMC version which allows the task-irrelevant information to undershoot when swinging back to zero. After considering the model fits, we present a second approach, where we implemented a cognitive control mechanism to simulate the influence of increased processing of task-relevant information or increased suppression of task-irrelevant information. Both approaches demonstrate that the suppression of task-irrelevant information is essential to create the typical CSE pattern. Increased processing of task-relevant information, however, could rarely describe the CSE accurately.

How expectations influence scene gist recognition: A diffusion model analysis.

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Session:
Posters: Decision Making and Evidence-Accumulation Models

When we perceive the world, visual input follows a meaningful structure, which can be considered as "grammar" of the visual scene, as the relationships between scenes have been learnt implicitly from the rules of the world like learning a language. For example, we expect to see scenes of the hallway – rather than a parking lot – when leaving an office. In the present study, we aim to disentangle the effect of expectations on the scene gist recognition process. In each trail of the experiment, participants will see a sequence of visual scenes, where the previous pictures serve as primes for the latter ones. The experimental design comprises three within-subject factors: We manipulate whether there is scene category change at superordinate level (i.e., a change from indoor to outdoor), whether there is basic-level scene change (e.g., a change from office to classroom), and whether there is high or low expectancy for target scenes. In the high expectancy condition, the primes and target will be displayed in a spatial temporal coherent sequence, whereas in the low expectancy conditions, primes and the target will be shown in a randomized sequence. We hypothesize that high expectancy will facilitate gist extraction and thus speed up response times and accuracy of scene categorization. Further, we expect that the facilitation effects result from faster speed of evidence accumulation (i.e., drift rate) in high expectancy than low expectancy. Besides, we also test for an effect of scene category change on the starting point of the diffusion process. To test these hypotheses, we fit diffusion model with parameters depending on different conditions using a hierarchical Bayesian parameter estimation procedure.

A Bayesian graphical model for matching law behavior

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Session:
Posters: Learning

In environments that have multiple sources of reward available simultaneously, organisms generally invest effort proportionately to exploit them. This general and robust behavioral finding is known as "the matching law" and has been documented in humans and several non-human species, under a variety of experimental variations as well as in observational settings. In a typical matching preparation, two alternatives of reward would pay at different rates. For example, alternative A would deliver, on average, two rewards per minute, while alternative B would deliver only one. Under these constraints organisms tend to invest, on average, twice as many resources exploiting alternative A than B. In other words, the matching law states that the relative rate of investment is a linear function of the relative rate of reward. The two parameters of the linear matching model represent, respectively, sensitivity to relative reinforcement rates and bias to some alternative regardless of its relative richness. The perfect matching relation is the special case of this linear model in which the organism shows equal sensitivity to all alternatives (slope 1) and no bias towards any (intercept 0). Deviations from that equilibrium constitute an active field of research in that they may account for suboptimal behavior. Crucial to this endeavor, especially when sample sizes are small, is the proper accounting of statistical uncertainty over inferred parameter values.

In this work we present a novel Bayesian graphical model to quantify matching behavior and show its potential by analyzing previously published datasets. The key contribution of the model lies in its generative nature: while most published analyses under the matching law framework summarize and collapse data across sessions, subjects, or both, our model is able to generate raw counts of responses directly for each individual under every experimental condition. Furthermore, hierarchical extensions of the model allow the inclusion of differences and effects both at individual and session level, paving the way for explanatory extensions to account for potential sources of optimal or suboptimal behavior. The Bayesian implementation we propose naturally quantifies the evidence in favor or against the matching equilibrium for each unit and for the hyperparameters that control their hierarchical distribution without loss of uncertainty. These novel tools may shed new light on a behavioral finding that has been central in animal decision-making over the last half century.

Extending the basic local independence model for the assessment of (un)learning items in knowledge space theory

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Session:
Posters: Learning

Probabilistic Knowledge Space Theory (PKST; Doignon & Falmagne, 1999) provides a set-theoretic framework for the assessment of a subject's mastery of items within a knowledge domain while accounting for response errors (i.e., careless errors and lucky guesses). For usage in longitudinal contexts, a skill-based extension of PKST has been suggested to incorporate two points of measurement (Anselmi et al., 2017; Stefanutti et al., 2011), where skills may be gained or lost from one point of measurement to the next, and the associated parameters for gaining and losing skills may vary between multiple groups. For some of these models, MATLAB code for maximum likelihood parameter estimation via the expectation-maximization algorithm (ML-EM) is available. Its known drawback of potentially inflating response error probabilities is dealt with by introducing (arbitrary) upper bounds for these parameters. In the present work, we develop models that extend the Basic Local Independence Model of PKST with parameters for gaining (or losing) item mastery between two points of measurement. We establish ML-EM parameter estimation and, in order to avoid parameter inflation, both a minimum-discrepancy (MD) method that minimizes response errors and a hybrid MDML method (Heller & Wickelmaier, 2013). All estimation methods are implemented in R. Results on parameter recovery and identifiability are presented.

Convergent hierarchical curiosity loops in a multi-objective intrinsic reinforcement learning agent

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Session:
Posters: Learning

During the learning process, the brain processes various sources, including sensory and motor input, memory, and attention. However, it can only produce a single output at a time, i.e. motor commands, which are crucial for actively controlling the learning process. In real-world scenarios, a reinforcement learning agent may need to balance multiple conflicting objectives. Furthermore, the field of artificial curiosity, in which intrinsic reward is linked to learning progress has gained much attention. Here, we are investigating the use of convergent intrinsic reward functions, which incentivize the agent to pursue learning goals that align with multiple objectives. Previous work in Multi-Objective Reinforcement Learning (MORL) with intrinsic reward has focused on developing algorithms that can optimize multiple objectives simultaneously while also incorporating intrinsic rewards to encourage exploration and the discovery of new strategies. These algorithms have used multi-objective optimization frameworks such as Pareto optimization and hierarchical RL to achieve this goal. To investigate the scenario of a learning agent with multiple sensory-motor learning objectives that can only take one action at a time, we generated a hierarchical composition framework, in which all possible learners are co-learned, each represented by a neural network that explores unique two-to-one correlations. This adaptable system has a generic structure and can adjust to different input types. These networks' learning progress is translated to intrinsic rewards, which were fed to a singular actor. Our findings indicate that certain networks achieve convergence, while others do not, which sheds light on the types of correlations that are learnable and those that are not. Moreover, the singular actor eventually develops a policy that produces more successful learning networks compared to random. This study has the potential to provide insights into how convergent intrinsic reward functions correlate with mechanisms underlying human cognition and behavior.

Catastrophes in learning: Dynamical system models for the reciprocal relation between practice and success

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Session:
Posters: Learning

We propose a dynamic system model for the investigation of the reciprocal relation between practice and success in learning under conditions of free practice, where practice leads to success and success reinforces practice. In free practice, one may quit, in contrast to forced practice, a case that has been extensively studied in mathematical learning theory. The forced 'law of practice' models studied in mathematical learning theory are the main building blocks of our model. It is shown that the equilibrium behavior of the reciprocal practice-success (RPS) model depends mainly on the choice of the 'law of practice' function. For concave practice functions, the resulting dynamics can be characterized as a fold catastrophe. For S-shaped practice functions, the behavior is governed by a cusp catastrophe, in which sudden transitions between optimal and deprived learning states occur. As such, the model offers new explanations for drop-out, the Matthew effect, and the development of expertise. The psychological interpretation of this model, its practical implications, and limitations are discussed.

Learning in the Context of Partial Information

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Session:
Posters: Learning

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, many classic models of category learning make a simplifying assumption that dimensions of information are perfectly encoded. Here, we investigate the merits of this assumption by evaluating categorization and memory performance in a categorization paradigm designed to discern learning strategies and partially encoded representations. We demonstrate how particular learning strategies and corresponding representations can influence generalization to novel stimuli presented in a testing phase. We build upon existing models of categorization to illustrate how partial encoding can account for differences in learning.

Modern Preference Learning Model Evaluation for Individual Discrete Choices

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Session:
Posters: Learning

Learning individual behavioral choice rules is difficult due to the malleability of choice rules, heterogeneity across individuals, and the limited availability of choice sets. Statistics and machine learning (ML) methods can perform choice rule estimation, but it is currently unknown what method can best estimate individual preferences without prior knowledge of the choice rules decision-makers will use. This study evaluates four preference learning models (Multinomial Logistic Regression, Generalized Additive Model, Twinned Neural Network, Gaussian Process) with respect to their capacity to learn and predict five choice rules that are important in behavioral science and mathematical psychology (Linear Strong Utility, Monotonic Strong Utility, Ideal Point, Lexicographic Semiorder, and Multiattribute Linear Ballistic Accumulator). Three Monte Carlo experiments were performed to assess model performance when increasing a) number of attributes in the choice alternatives, b) number of training choice sets, and c) choice rule determinism. The results indicate that some models can outperform others for individual choice rules. For example, GAM outperforms other models using limited choice sets in recovering Linear Strong Utility by 0.004 (Twinned Neural Network), 0.016 (Multinomial Logistic Regression), and 0.027 (Gaussian Process), as measured by Brier Score. However, no model dominates in performance across all choice rules and contexts. Model performance improved by 8% to 68% in Brier Score with an increase in training choice sets and improved by 1% to 63% with an increase in choice rule determinism, but the impact of number of attributes differs by choice rule and model.

Using multidimensional scaling and convolutional neural networks to probe mental representations of complex images

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Session:
Posters: Perception, Cognition, Memory, Neuroscience, Language

Understanding the mechanisms of anxiety disorders requires an understanding of how fear-inducing stimuli are mentally represented. Because similarity is central to recognizing objects and structuring representations, similarity judgment data are often used in cognitive models to reveal psychological dimensions of mental representations. However, both collecting similarity data and predicting the positions of newly added objects in the existing database are resource-intensive. Thus, previous studies mainly focused on small-scale databases, and characterizing representations for large-scale fearful stimuli is still limited. In this work, we conducted an online experiment using a large image database of 314 spider-relevant images to collect similarity judgments. Participants first completed the Fear of Spider Questionnaire (FSQ). We then used a rejection sampling method to select participants and ensure that the resulting FSQ scores were uniformly distributed. Next, selected participants performed the Spatial Arrangement Task, in which they arranged spider images on a 2D canvas according to the subjective similarity between each pair of images. With the collected data, metric multidimensional scaling (MDS) was applied to create low-dimensional embeddings. We compared Bayesian information criterion and cross-validation as model selection procedures in a simulation and these two methods were used to determine the dimensionality. We then reproduced these embeddings and predicted the positions of new images using convolutional neural networks (CNNs). Taken together, this work explores the application of MDS and CNNs to large-scale complex images for the first time, and the methodology employed could be applied to a wide range of stimuli in psychological research.

About cross-modal commutativity in magnitude production

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Session:
Posters: Perception, Cognition, Memory, Neuroscience, Language

Can we compare the loudness of a tone to the brightness of a light? The answer is yes. We are intuitively capable of these cross-modal comparisons. Psychophysical researchers such as Stevens have long assumed that these cross-modal comparisons are mediated by a single scale of subjective intensity. Luce (2002) developed a psychophysical theory for physical intensity making Stevens' assumptions towards an underlying scale of perceived intensity explicit and formulating empirically testable conditions for it. They identified cross-modal commutativity as a property through which the theory can be tested. We investigated this property in a cross-modal magnitude production task between auditory and visual stimuli, concerning their loudness and brightness respectively. Participants were presented with the two stimuli and instructed to, for example "make the tone 3 times as loud [as the visual stimuli appears bright]". This was partly a replication of Ellermeier et al. (2021). They concluded that cross- modal commutativity holds whereas we find inconclusive evidence in a Bayesian analysis. More importantly, in a theoretical analysis, we find evidence that role-independence of the internal references used in magnitude production is violated. In an expansion of Luce's theory, Heller (2021) concluded that cross- modal commutativity holds if and only if the internal references are role-independent, meaning they are not dependent on whether the reference pertains to the standard or the variable stimulus. This means, if role-independence of the internal references is violated, the assumed intensity scale can hold even if cross- modal commutativity doesn't. Evidence towards this conclusion as well as its implications will be discussed.

Integrated information to predict consciousness state - An exploratory analysis

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Session:
Posters: Perception, Cognition, Memory, Neuroscience, Language

Integrated Information Theory (IIT) is considered the most advanced formal theory of consciousness within neuroscience literature. However, only limited and indirect empirical evidence supports IIT. Computational, empirical, and theoretical limitations make it hard to test the predictions of IIT. To verify the hypothesis that higher values of integrated information (PHI) are associated with a higher level of consciousness, we leveraged data collected by two previous studies (Taghia et al., 2018; Huang et al., 2020). Such data is amenable to an IIT analysis employing the PyPhi toolbox (Mayner et al., 2018). In both studies there are conditions associated with different levels of consciousness (e.g., sedated participants vs controls as in Huang et al., 2020) and a transition probability matrix between brain states, obtained by means of machine learning techniques. We investigated if integrated information is able to predict consciousness level based on the state-by-state matrix generated according to transition probabilities. We observed that the PHI values are not related with conditions where brain states are characterized, according to neuroscience literature, by a greater consciousness level. Finally, we discussed limitations and future opportunities of our approach.

Cascading transitions in multistable perception and cognition

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Session:
Posters: Perception, Cognition, Memory, Neuroscience, Language

Human nature comprises multilevel complex systems, and we hypothesize that these systems undergo critical changes through cascading transitions. For example, individuals who become extremists are often part of a massive societal shift, such as polarization. To model these complex systems, we aim to develop a general mathematical model of cascading transitions. For this purpose, two simplified cases will be tested: multifigure multistable perception and logical paradoxes. Our work builds on previous models and experimental studies of single multistable figure perception and binocular rivalry. We hypothesize that different cases of multifigure multistable perception and logical paradoxes can be represented as unique instances of the general model for cascading transitions. We will examine fundamental phenomena, create and test new predictions, and employ innovative experimental designs and recently developed psychophysiological measurement methods. In addition, we will apply eye-tracking and EGG techniques to novel situations. We will fit cascading transition models to psychophysiological data to advance our understanding of these models. Furthermore, we will expand this newly developed theory to include logical reasoning and multimodal perception. The expansion of a quantitative theory of cascading transitions will offer a tangible societal impact by improving our understanding of psycho-social systems. In conclusion, the core objective of this study is to examine whether the cascading transition model could serve as a thorough explanation for both multifigure multistable perception and logical paradoxes.

Connecting the sample size of mental sampling with working memory capacity

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Session:
Posters: Perception, Cognition, Memory, Neuroscience, Language

The sampling framework has been proposed to provide an integrative perspective of how people make probability judgments. It posits that people approximate probabilities by drawing mental samples from memory or mental simulation. Sampling-based models have successfully reproduced a wide range of observed effects in probability judgments. Yet, they have also been criticized for lacking a robust coupling of model terms and psychological processes (Coenen, Nelson, & Gureckis, 2018). We addressed this critique by testing the positive association between an important model term – the sample size of mental sampling – and individual differences in working memory capacity (WMC). Such a relation has been widely assumed in the sampling framework (e,g., see Lloyd et al., 2019). Nevertheless, as far as we know, the validity of the assumption has yet to be investigated. Here we use the coherence of people's probability judgments as a proxy of sample size, as larger samples are less vulnerable to sampling variability. Therefore, an empirical examination of the association between WMC and coherence would provide evidence for the assumed positive relation between WMC and sample size. To measure coherence in probability judgments, we adopted the novel event-ranking task proposed by Liu et al. (in prep). In such a task, participants are asked to provide rankings for different sets of events, each consisting of two pairs of complementary events, {A, not-A, B, and not-B}. A logically correct ranking follows the complement rule, such that when A is ranked above B, not-A is ranked below not-B. The probabilities of participants providing logically correct (versus incorrect) ranking would manifest the level of coherence in probability judgments. The present study critically examined the assumed link between the sample size of mental sampling and WMC, thereby contributing to the theory-testing of the sampling framework.

Cognitive and neural underpinnings of cognitive control in the Dot-Pattern Expectancy Task.

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Session:
Posters: Perception, Cognition, Memory, Neuroscience, Language

Continuous Performance Tasks (CPTs) are widely used for assessing cognitive function in psychological, psychiatric, and neurological disorders. The present study seeks to establish the construct and predictive validity of a commonly used CPT - The Dot Pattern Expectancy Task (DPX), by showing how neural measures relate to specific patterns of behavioural performance. To achieve this, we first fit generative models to parse individual biases and parameters that characterise the evidence accumulation process at a single-trial level. Second, we investigate whether electroencephalographic (EEG) activity recorded during the same task tracks individual differences in the cognitive modelling parameters. Results indicate that evidence accumulation models can, in principle, separate preparatory and corrective mechanisms in the DPX. In addition, different spatiotemporal patterns of evoked activity correlated with different model parameters allowing a finer-grained, theory-driven perspective on cognitive and neural processes underpinning variability in CPT performance.

Using ACT-R to model racial biases in a semantic knowledge graph

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Session:
Posters: AI and ACT-R

ConceptNet is a semantic knowledge graph made with the intention of drawing conclusions between words and expressions. This semantic network intakes information from various databases, largely originated from text gathered from online websites, defines the relationship between words based on the context in which it was found being used and assigns a relational strength between each of the words. But due to the sources of these datasets and degree of human influence over the spaces that this data is collected from, biases have been detected in the relationship aspects of this network. Our work focuses specifically on the racial biases that have multiplied in this environment. By using this network as a declarative memory knowledge source in a cognitive architecture, we can dissect some of these relational values and gain further insight into how the conceptual space of Blackness is treated among these representations and what this means for cognitive processes and behavior. While we are aware of (canonical) ACT-R's capability of representing a semantic knowledge graph, our goal with this model is to create an extended declarative memory that would hold the knowledge that ConceptNet contains—which consists of well over 1 million nodes. We plan to use this extended ACT-R system to understand the socio-cognitive processes used by participants in a human-AI cooperation study by Atkins et al. (2021). The study reported by Atkins and colleagues explicitly explored how (likely implicit) racialization of AI agents might affect human cooperation with those agents during a task. Thus, a cognitive model for that task would need some representation of sociocultural knowledge, particularly knowledge to represent the conceptual space of systems of oppression that result in racial categorization and racialization.

The Comparison of Operating System Timing Performances in Interval Timing Study Using the AGI

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Session:
Posters: AI and ACT-R

Timing accuracy is very important in human behavioral experiments, especially in time perception experiments. In this study, the prospective interval timing experiment conducted by Taatgen, van Rijn, and Anderson in 2007 was repeated using the ACT-R Graphical User Interface (AGI) to compare the timing performances of operating systems. Considering that almost all psychology experiments are run on operating systems that require a multitasking environment today, it can be said that under which conditions such operating systems provide timing accuracy is an important practice that researchers should acquire. Ensuring such precision on a computer can be challenging, especially when using multitasking operating systems like Windows, UNIX, or Linux. Therefore, the experiment developed using Python programming language and AGI was tested on both Windows and Linux operating systems to evaluate duration of the experiment. The original experiment had four different conditions, there are three of these conditions in this study. In each phase, the task was either Letter or Addition. These three conditions are as follows: The LLL condition with only letter task, the AAA condition with only addition task, and the AAL condition with both addition and letter task. In this study, prospective interval timing performance is evaluated, thus timing accuracy is important. In the original experiment trial duration is 13 s. However, when the timer duration has been set as 13 s in the Python code, it is observed that the trial duration lasted almost twice this time. To solve this issue, a mathematical function that calculates the deviation has been added to the code. Although the deviation was minimized with this function, the trial duration was not precisely 13 s. It is thought that the reason for this problem is weak timer resolution of the AGI. Apart from that, the performance and hardware specifications of the computer systems can differ, which can impact the time taken for the code to execute. After analyzing the data, it has been found that the average durations of the AAA, LLL, and AAL conditions when run on the Windows operating system are 13.35 s, 14.11 s, and 10.76 s, respectively. Similarly, the average durations of these same conditions when run on the Linux operating system are 13.28 s, 13.77 s, and 10.6 s. Based on the results, it can be observed that the experiment runs for comparable durations on both operating systems. However, upon examining the averages, it appears that the experiment runs slightly faster on Linux. Linux is known for its efficient file system and memory management, which reduces the amount of overhead required to run the operating system. So, this efficient memory management allows Linux to run faster and smoother, even on older or less powerful hardware. According to the results of the study, despite the timer resolution of AGI is not constant in itself, it can be seen that the experiment developed with Python and AGI work stably on both operating systems. Considering that AGI's timing performance is dependent on many factors, including task complexity and computer hardware, this study shows that AGI has consistent timing performance in different operating systems.

Comparing Capacity Estimates for Genuinely No-signal vs Target Absent in Systems Factorial Technology

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Session:
Posters: AI and ACT-R

Ideally, the capacity of a single channel in a multichannel system should be unaffected by task type (e.g, logical "AND" vs "OR" tasks). However, Howard et al. (2021) reviewed studies in which capacity estimates for "AND" tasks differ greatly from "OR" tasks. In the classic definition of capacity, the absence of a component is not explicitly considered. They suggest a need to incorporate processing time random variables from the no-signal channels into the capacity formulation. We recently collected data from the standard double factorial paradigm that allows us to evaluate the utility of this modification. In one experiment, observers detected the presence or absence of components in Navon-like stimuli (i.e., global shape is composed of local shapes) for both the "OR" and the "AND" task instructions. Absence of a target feature was the presence of a neutral distractor. Hence, the no-signal channel actually contained shape information. In contrast, a second experiment used complex Gabor patches composed of two sinewave gratings in the same tasks. Hence, the absence of one grating does imply nothing is present on that channel. We show that modifying the classical capacity coefficient to account for empty channels is more effective for Gabor patches when compared to the Navon stimulus example.

Playing with Memory: Working Memory Development in Primary School

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Session:
Posters: Applied and Meta-Science

Working memory, a cognitive system involved in the retention and manipulation of stored information, plays a critical role in many cognitive processes and in cognitive development. Understanding how WM processing develops over time and how it interacts with education is critical for improving cognitive outcomes in children. In this study, we analyzed data from a large online adaptive learning platform to examine the development of working memory (WM) processing in children. Data were collected from elementary school students between grades 3 and 8 who played two different working memory games, a verbal WM task, and a visuospatial WM task. Using item response theory, multilevel modeling, and cognitive modeling, we examined classic WM benchmarks to gain insight into the dynamic developmental trajectory of WM processing. We found that item characteristics, particularly set size, affect item difficulty across the age range. We also investigated primacy and recency effects and found that position effects vary across age groups, suggesting that there are dynamic changes in WM processing as children grow older. Finally, we analyzed different types of errors and found that children were more likely to forget an item than to add or repeat it. However, as children matured, we observed a decreased tendency to forget items but an increased tendency to erroneously repeat them. Our findings provide an understanding of the dynamic development of WM processing in children and highlight the robustness of classical WM findings.

Modeling memory impairments in cancer survivors: Impaired retrieval processes

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Session:
Posters: Applied and Meta-Science

Cognitive impairment is an often-overlooked issue that cancer survivors face, with a third of non-CNS cancer survivors reporting memory problems. Memory, however, is complex and consists of various underlying cognitive processes. The objective of this research is to investigate memory problems more thoroughly in cancer patients. This was done through an adapted Hierarchical Bayesian cognitive model from the Alzheimer's Disease literature, which splits memory into several processes relating to either learning or retrieving words from any of three memory states (unlearned, partially learned, learned).

Participants were cancer survivors (n=187) of various non-CNS tumors (breast, prostate, and others) who received various cancer treatments (chemo-, endocrine-, radio- and immunotherapy) and no-cancer controls ($n = 204$). The participants completed the Amsterdam Cognition Scan (ACS), in which classical neuropsychological tests are digitally recreated for online at-home administration. The specific test used to investigate verbal memory was the ACS equivalent of a Verbal Learning Test, in which participants are tasked with recalling a list of 15 words five times. Later in the test battery the participant is asked to recall these 15 words again, as a delayed recall trial.

A traditional analysis of the sum of trials 1-5 indicated a small effect size difference between patients and controls, $t(385.23) = 2.81, p < .01, d = .28$. There was no significant difference between patients and controls in the delayed recall trial. For the underlying memory processes, significant differences were found in the immediate retrieval process parameters, both retrieval from a partially learned state ($t(378.47) = 2.6, p < .01, d = .26$) and retrieval from a learned state ($t(381.57) = 2.44, p = .02, d = .25$). No differences were found in any parameters related to learning processes, nor in the delayed retrieval process parameter.

The results indicate that the memory problems in cancer survivors are likely due to selective impairment of memory retrieval processes, rather than through learning impairment or a general impairment.

Researcher diversity, equity, and inclusion: A critical blind spot of the computational modeling movement within psychological science

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Session:
Posters: Applied and Meta-Science

Computational psychology is a growing field that uses computer simulations and mathematical modeling to explain and predict complex behavior in psychology, psychiatry, and neuroscience. It is now one of the priority areas for research funders, scientific journals, and faculty hiring. However, anecdotal evidence has always pointed to longstanding diversity issues in the field with a lack of representation among women and black individuals. We sought to move beyond anecdotal accounts and examine the extent of these disparities in awards given and authorship of peer-reviewed articles. Our goal was to highlight the need for increased diversity, equity, and inclusion (DEI) within computational psychology. Name-based classifiers were used to estimate individuals' gender and race based on first and last names. From these classifications, we examined demographic trends among N=27,163 authors and N=390 award-winners in preeminent journals/societies across computational psychology (including computational psychiatry, mathematical psychology, and computational neuroscience), psychology/neuroscience, and computational science. Results indicated that women represented just 23% of authors and 15% of award-winners within computational psychology—markedly lower than computational science (authors: 29%) and psychology/neuroscience (authors: 40-47%; award-winners: 38%). Black individuals were underrepresented among authors (2-4% of authors in computational science and psychology/neuroscience), but representation was lowest in computational psychology, where black individuals represented a mere 0.8% of authors. Taken together, these findings highlight major gender and racial disparities among computational psychology researchers. Evidence suggests that diverse teams tend to show better performance, more creativity, and produce more novel, high-impact science. Therefore, these disparities emphasize the necessity of targeted efforts (e.g., outreach, mentorship programs) to increase DEI within computational psychology to ensure equitable access to resources and promote scientific advancement.

Towards a formal model of addiction in individuals

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Session:
Posters: Applied and Meta-Science

We aim to create an explanatory formal model for addiction. We deem earlier attempts to create this type of model for addiction too complex and thus we propose to use just one ordinary differential equation:
$dN/dt = r * N * (1 - N/K) - (B * N^2)/(A^2 + N^2)$
This equation has been studied extensively since originally proposed by Ludwig et al. (1978) to model the outbreak of spruce budworms. From only the first term it would follow that N grows with rate r until limit K is reached. However, the second term controls the growth of N. The larger B in the second term the more the growth of N is controlled, with maximum control of the growth at A. How these parameters are interpreted in addiction depends on the specific type of addiction. In general, N can be thought to represent the consumption of an addictive substance or the frequency with which addictive behavior occurs. The r can be interpreted as the rate at which consumption leads to more consumption, which could for example be influenced by brain processes and peer pressure. B could represent the upper limit of self-control, which is reached if consumption gets so high that behavioral control is lost. $1/A$ can be thought of how fast self-control starts to influence behavior, which can for example be influenced by the social environment and beliefs about the consequences of the addictive behavior.
The equilibrium states of the model we propose can be described by a cusp catastrophe model. In the cusp, there are two stable states, which could correspond to problematic or non-problematic behavior in terms of addiction. The behavior of the cusp catastrophe model can reproduce some of the important phenomena that are present in addiction. For one, quitting in addiction is hard, which corresponds to the hysteresis effect that we see in the cusp. Moreover quitting and relapsing are often sudden phase transitions just as can occur in a cusp catastrophe model. The cusp model also allows for more gradual changes which can be more appropriate for the initial transition to problematic behavior or substance use.

How do doctors use the quantitative and quantitative probability language to communicate the chances of pregnancy in fertility treatment contexts.

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Session:
Posters: Applied and Meta-Science

I am broadly interested in applied statistics with particular emphasis on cognitive psychology. In particular, my current project explores how doctors and patients use the qualitative and quantitative probability language to communicate the chances of pregnancy in fertility treatment contexts. Doctors commonly use probabilistic language when communicating the evidence-based chances that a treatment will be successful. When asked about terms used by doctors — such as that pregnancy is "likely" or has "little chance" — doctors and patients showed heterogeneity in both their behavior and their ordinal rankings of terms and their quantitative ratings. Specifically, the wide variety between and within individuals in terms of their judgement of probability estimates across contexts; the fatigue from participants causing the individuals fluctuation among a long list of identical probability terms (e.g., likely, probably, probable, better than even, unlikely etc.). Furthermore, a pairwise correlation test between participants' ranking responses explicitly showed three clusters within the dataset. The clusters illustrated three types of participants in the dataset, who ranked the terms in the requested order; a small proportion of participants ranked the terms in a reversed order; and some compiled the task partially. I am interested in formally modeling the probability judgements to understand both differences across people within a group (individual differences) and differences between groups (doctors). In the results of the data analysis, I am looking forward to providing insightful and referable guidance for doctors so that they have a certain level of knowledge regarding if using probability language actually facilitates the clearness of a conversation. If that is helpful, what specific forms or certain words are recommended in the fertility conversations. By studying the unique characteristics fertility patients might have in terms of understanding probability language, they are expected to benefit from both emotionally and physically because more understandable information can be derived from the effective communication facilitating their decision-making process. Therefore, all sources of heterogeneity should be taken seriously in the data analysis in expecting a meaningful result.

Role of racial implicit associations on numerical estimation of faces

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Session:
Posters: Social

Prior research has pointed to the role of emotion on the estimation of quantity. For instance, angry faces tend to be overestimated in number, but their presentation durations are more accurately reproduced. One of the mechanisms underlying these findings is that threatening faces, which activate the amygdala, might demand greater attentional resources, thereby causing better accuracy and overestimation. In a separate line of work, skin tone bias has been shown to moderate race-related amygdala activation, with other-race faces yielding greater amygdala activation than own-race faces. Further, the level of amygdala association appears to be linked to implicitly held biases. Namely, individuals who showed the strongest associations, as measured by the Race Implicit Association Test (IAT) showed the greatest amygdala response to other-race faces. The IAT is an indirect measure of association between positive/negative evaluations (eg, good vs. bad) and social groups (e.g., Black vs. White). This attentional preference for other-race faces has also been observed in behavioral measures. For instance, in visual search and perceptual discrimination tasks, White participants detected Black target faces faster than they did White target faces. An important question is whether the overestimation effects found in estimating angry faces are also found when estimating other-race versus own-race faces. If other-race faces yield greater amygdala activation and demand greater attentional resources similar to the processing of angry faces, then we should expect to find an overestimation of other-race faces versus own-race faces. Furthermore, given that implicitly held biases moderate the level of amygdala activation, we should expect to see the greatest overestimation of other-race faces in those with the greatest implicit biases. The present study examines the performance on a numerical estimation task, during which participants are shown an array of faces and asked to judge whether there are more Black faces or White faces. All participants then complete a race IAT. The central question is the extent to which implicit associations drive estimation measures for own versus other-race faces. The findings from this study will fill a crucial gap in the literature on the role of attention, arousal, and other-race bias on numerical estimation tasks.

Transitions in Synchrony and their Effects on Affiliation: an Adaptive Dynamical System Model

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Session:
Posters: Social

Interpersonal synchrony is associated with stronger interpersonal affiliation. No matter how well-affiliated people are, interruptions or other transitions in synchrony rebound to occur. One might intuitively expect that transitions in synchrony negatively affect affiliation or liking. Empirical evidence, however, suggests that time periods with interruptions in synchrony may favor affiliation or liking even more than time periods without interruptions in synchrony. This paper introduces an adaptive dynamical system model to explain how persons' affiliation might benefit from transitions in synchrony over and above mean levels of synchrony. We evaluated the dynamical system model in a series of simulation experiments for two persons with a setup in which a number of scenarios were explored where different (time) episodes occur. The designed adaptive dynamical system model can be used to model the interaction in therapy or counselling sessions. Its dynamics describe not only the emergence of interpersonal synchrony in such sessions and its adaptive effect on affiliation between therapist or counsellor and client, but also regularly occurring transitions of such synchrony and their adaptive effect.

Examining the relationship between environmental distributions and belief

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Session:
Posters: Social

In a complex and volatile environment, agents must learn to capitalize on regularities in their surroundings to be able to infer unknown quantities and generalize past knowledge. However, what properties are learned when adapting to environmental regularities is still unclear. One possibility is that only a few representative examples are stored in memory (Mozer, Pashler, & Homaei, 2008). Alternatively, one could infer rough summaries of the distribution of instances, such as the expected value over all instances and their variability (Tran, Vul, & Pashler, 2017). Finally, agents might acquire full distributional knowledge about environmental regularities, for instance, that instances are distributed according to a powerlaw distribution (Griffiths & Tenenbaum, 2006). These accounts differ in complexity and, as a result, in their ability to capture complex environmental distributions. Intuitively, an agent should strive to match the environmental statistics as closely as possible, with an ideal observer considering the exact environmental statistics as prior information when performing inferences. //However, this intuitive notion has been challenged based on theoretical arguments and simulations, arguing that reproducing the environmental frequencies exactly is not robust to possible environmental changes and amounts to overfitting. Instead of veridical environmental frequencies, ideal observers should favor more entropic prior beliefs (Feldman, 2013). Here, we test this argument empirically by contrasting people's beliefs about everyday statistics with their corresponding environmental frequencies. By adopting a novel elicitation technique, random generation as belief elicitation (León-Villagra et al., 2022), we gain access to people's belief distributions for a set of eight domains with different distributional properties. Participants ($N = 120$) produced random draws from everyday quantities (e.g., cake baking times, movie lengths, life expectancies), uttering each item aloud. We transcribed the sequences of utterances, obtaining a trace of "random" draws. Then, we compared the distributions resulting from these draws and the entropy of these distributions to the corresponding environmental distributions and their entropy. We found a significant effect of the domain on the participants' belief entropy, with six out of eight domains resulting in participants exhibiting higher entropy than the environmental data. Our results provide initial evidence for Feldman's theoretical argument for agents' learning beliefs that are more entropic than their encountered environmental frequencies.

Investigating the belief bias in everyday political reasoning

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Session:
Posters: Social

The belief bias is most often investigated with syllogisms varying on two dimensions, logical validity (valid vs. invalid) and believability (believable vs. unbelievable). Typically, participants can distinguish valid and invalid syllogisms (albeit imperfectly), but are also more likely to rate syllogisms as logically valid if they have a believable versus unbelievable conclusion. Additionally, the ability to distinguish between valid and invalid syllogisms can be reduced when their conclusions are believable compared to when they are unbelievable. However, syllogisms are formal reasoning forms unlike arguments we typically see in everyday or informal reasoning. We investigated the belief bias effect in the context of everyday arguments regarding controversial political topics such as those encountered on (social) media (e.g., 'abortion should be legal'). Arguments in our study differ in their (informal) argument quality; 'good' arguments provide an explanation for their conclusion, whilst 'bad' arguments do not provide an explanation and contain a reasoning fallacy (e.g., appeals to authority). Participants rated their beliefs about a series of political claims on a scale from 1 to 7 and rated the strength of 'good' and 'bad' arguments about these claims on a scale of 1 (extremely bad argument) to 6 (extremely good argument). Participants exhibited the belief bias effect for everyday arguments; they consistently rated good arguments as stronger than bad arguments, but were also biased in rating arguments in line with their beliefs as stronger than arguments that were not.
The interaction between the quality of an argument and participants' beliefs about the claims that argument makes is unclear. If we assume the belief and argument strength rating scales are continuous and the relationship between these variables is linear, we fail to find evidence of this interaction using a linear mixed model. However, if we analyse the data using a signal detection approach after binarising the argument strength ratings we find evidence for an interaction, but in an unexpected direction. The ability to discriminate between good and bad arguments increases with the strength of participants' beliefs about these arguments. The difference in these results is possibly due to assumptions of a nonlinear relationship between the variables in the latter model and raises questions about the most appropriate way to measure the belief bias in everyday reasoning.

Unfreezing attitudes: Understanding pretest sensitization in the Ising attitude model

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Session:
Posters: Social

Van der Maas and colleagues (2020) have recently proposed a mathematical model of opinion formation using Ising networks of attitude elements in order to study polarization and attitude formation A fundamental aspect of this type of network is that it allows for continuous as well as discrete behavior; attention/involvement polarizes attitudes. When individuals are not highly involved in a topic, new information gradually shifts their opinions. However, when individuals are highly involved, their opinions are discrete and require more information to change. This implies that to change someone's opinion, we need to manipulate information without increasing attention. However, explicit attitude measurements can unintentionally increase attention (mere thought effect; Tesser 1978), which has important implications for standard experimental designs. Pretest questionnaires can "freeze" the network, making it difficult for interventions to have an effect - this constitutes a new explanation of an effect known as pretest sensitization. On the other hand, this "freezing" effect may be beneficial for posttesting as this may preserve the effect of the intervention.

We propose a study using an extension of the Solomon four-group design to test these hypotheses and identify the most appropriate experimental designs for testing opinion change. In addition to the four-group design (1. pretest-intervention-posttest, 2. pretest-posttest, 3. intervention-posttest, and 4. posttest), we will include three additional conditions: 5. an early pretest-intervention-posttest condition to test whether pretest-induced involvement fades, 6. an intervention-delayed posttest condition and 7. an intervention-posttest-delayed posttest condition to test the effect of posttest intervention preservation.

The polarizing effect of attention can have important implications for attitude change interventions and experimental designs, highlighting the need to carefully consider how to measure attitudes and control for potential confounding factors. This study can further advance our understanding of attitude formation and help develop effective strategies for changing attitudes.

Exploring human representations of facial affect by integrating a deep generative model into Markov Chain Monte Carlo With People

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Session:
Posters: Social

People's internal representations of natural categories play a crucial role in explaining and predicting how people perceive, learn, and interact with the world. One of the most powerful methods for estimating these representations is Markov Chain Monte Carlo with People (MCMCP) which uses pairwise decisions to sample from very complex category representations. Unfortunately, MCMCP requires a large number of trials to converge, particularly for high-dimensional stimuli such as faces. To address this shortcoming, we integrate a deep generative model, specifically a Variational Auto-Encoder (VAE), into MCMCP, which reduces the dimensionality of the search space and accelerates convergence by using VAE's implicit knowledge of natural categories. VAE provides MCMCP with a compact and informative representation space via a non-linear encoder, and then focuses human decisions in areas of the representation where the VAE believes the category to be. Otherwise, MCMCP would search in a highly sparse representation space aimlessly until reach its target areas with greater gradients, which is typically lengthy. To test this approach, we ran a new experiment applying VAE-guided MCMCP to recovering people's representations of happy and sad faces. While past applications of MCMCP to facial affect categories have required chaining across participants, consuming thousands of pairwise decisions before obtaining representative estimates of the means of the two categories, VAE-guided MCMCP converges on an individual's representation within a single session of less than 150 trials, making MCMCP much more feasible. The study not only provides a method that enables MCMCP to uncover human representations of natural categories more efficiently at individual level, but also provides an innovative and generalizable framework that uses deep neural networks to enhance research into human internal representations.

Careless responses in questionnaire data: A knowledge structure perspective on the detection performance

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Session:
Posters: Experimental Design and Tasks

The detection of careless responses in questionnaire data is of increasing importance in a time online surveys and web-based experiments. There are many statistics that aim at detecting careless responses in already collected data. Based on classical test theory and item response theory these indices have been tested and compared. But until now no evaluation is available from the perspective of knowledge structure theory. We compared representatives from various classes of indices within a simulation study based on knowledge structure theory. For two subscales of the Freiburg Personality Inventory (Fahrenberg, Hampel, & Selg, 2001) derived from the respective normative sample, knowledge states and response patterns were simulated. Careless responses were characterized by increased careless error and lucky guess rates, or systematic responses (e.g., answering ”no” throughout). The number of careless responders and the extent of their carelessness were varied. Signal detection theory was used to evaluate the performance of the indices.

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Bayesian hierarchical Ornstein-Uhlenbeck models for intervention designs

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Session:
Posters: Experimental Design and Tasks

The Ornstein-Uhlenbeck (OU) model represents time series data as mean-reverting stochastic processes that gravitate towards a particular level. The OU model is widely used in fields such as finance, physics, and biology to model the dynamics of non-linear time series data. The model has three main parameters, namely the attractor, the elasticity, and the volatility, which are interpreted as the steady-state level of the variable, the speed of reversion to the mean, and the intensity of random fluctuations around the mean, respectively. Hierarchical Bayesian implementations of the OU model allow for flexible and robust data analysis by incorporating population-level parameters and individual-level heterogeneity. It also allows flexibility in the structure of the model, so that we can include time-varying parameters, latent class indicators, and relevant prior information. We apply a Bayesian hierarchical OU model to data from a mobile health intervention design aimed at promoting psychological well-being in college students. The model allows us to estimate the effectiveness of the intervention on psychological well-being over time, the persistence of the effect after the intervention, and to identify individual-level features of the response to the intervention.

Assessing Subject Parameter Recovery in Extended Encoding and Updating M3 Models: Implications for Experimental Design

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Session:
Posters: Experimental Design and Tasks

The memory measurement model framework (M3; Oberauer & Lewandowsky, 2018) comprises a collection of cognitive measurement models that isolate parameters associated with distinct working memory processes in widely used tasks such as simple or complex span and memory updating. By transforming activation of item categories into recall probabilities, the model framework estimates contributions of memory processes to working memory performance. We assessed the parameter recovery of the extended encoding and updating models within the M3 framework using our own hierarchical implementation in STAN.

We assessed the subject-parameter recovery of the complex span extended encoding and updating models, with a particular focus on time-dependent parameters for removal, extended encoding, and extended updating, and the time-independent parameter for immediate deletion. Simulations revealed difficulties in recovering the time-dependent removal parameter in both models, while recovery for the extended encoding and extended updating parameters was sufficient under certain conditions. The time-independent immediate deletion parameter could only be recovered sufficiently with a disproportional amount of data.

Based on the simulation results, the current state of the extended encoding and updating models of the M3 framework does not allow the estimation of subject-level parameters with reasonable efficacy and precision. We provide recommendations for experimental designs to maximize parameter recovery and discuss possible workarounds to improve subject parameter recovery.

Risky choices with potentially 'fatal' outcomes: Introducing the Extinction Gambling Task

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Session:
Posters: Experimental Design and Tasks

Humans often need to make choices that trade off a benefit against a small chance of extinction (e.g., death or even human extinction). We developed a novel risky-choice gambling task, the "Extinction Gambling Task", to study how people reason about these types of events. In the Extinction Gambling Task, participants need to decide between a risky gamble (with a higher expected payoff but a small chance of extinction) and a safe gamble (lower expected payoff but no chance of extinction) across a series of trials (100 in our study). Our task has two possible payoff structures to model extinction risk: In the "complete extinction scenario" drawing the extinction option implies that all past earnings are wiped out and that no earnings can be accumulated in future trials. In the "opportunity cost extinction" scenario, extinction merely implies that the participant cannot earn additional money in trials after the extinction event; however, they can keep their earnings from previous trials. We derived optimal decision strategies for both of these scenarios and validated them against simulations. In the "complete extinction case", the optimal strategy only considers the probability of the risky choice and the number of trials but not the order in which choices are made. In the "opportunity cost extinction" case, the optimal strategy considers both the probability of risky choices and the order in which choices are made. Compared to the complete extinction scenario, the optimal number of risky choices is higher in the opportunity cost case. Furthermore, the optimal strategy in the opportunity cost case involves first playing safe and switching to solely playing the risky gamble towards the end of the experiment.

We compared participants' performance across both scenarios in a between-participants design where each participant played one round of 100 trials. We found that (1) people are far too risk-seeking in early trials, which leads a large proportion of participants to become extinct relatively soon, and (2) for participants in the opportunity cost condition, the first choice of the risky gamble is later than for participants in the complete extinction condition, indicating that participants have some understanding of the different affordances of the two scenarios. Further, participants qualitatively follow the optional strategy by increasing the proportion of risky choices towards the end in the opportunity cost condition of the experiment, whereas participants in the complete extinction case do not show this pattern. We will present results from a mixture model describing different groups of participants. The "Extinction Gambling task" is a promising approach that can shed light on human decision processes with important real-world implications.

Error analysis and error modeling

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Session:
Posters: Statistics and Bayesian Models

For both designing interfaces and understanding learning, it is important to include error analysis to understand where time goes and how learning happens. Using data from a previous study (Ritter et al., 2022), this paper examines errors that participants make while doing a broken component-finding task. This study chose data from the testing session after one or more training sessions. Errors for each task and each partici¬pant were analyzed, including the misreplaced components for each task. Different from previous text editing tasks where errors were analyzed, this fault-finding task only needed participants to move the mouse and click on the broken component in an interface, so we came up with similar but different error categorization from previous literature. We also present an updated strategy model that generates errors and corrects errors for participant 421, ending up having a better correlation with the participant's performance.

Seeing What You Believe: Cognitive Mechanisms of Flexible Integration of Priors in Visual Decisions

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Session:
Posters: Decision Making and Evidence-Accumulation Models

Beliefs and expectations, or priors, shape our perception of the environment (Gold & Stocker, 2017). In an ever-changing world, priors must be flexibly and continuously integrated into sensory decision processes to guide adaptive behavior. Nonetheless, its underlying cognitive mechanisms are not well understood. The Drift Diffusion Model (DDM) is a widely used model for studying visual decision-making (Gold & Shadlen, 2007; Ratcliff & Rouder, 1998). Previous studies have shown that priors can increase the starting point of evidence accumulation and the drift rate (Dunovan & Wheeler, 2018; Dunovan, Tremel, & Wheeler, 2014; Thakur, Basso, Ditterich, & Knowlton, 2021). However, these studies often overlook the potential effects of priors on decision threshold and non-decision time parameters. The goal of this study was to dissociate the effects of priors on multiple cognitive mechanisms in visual decisions. Specifically, I tested how the strength of prior beliefs affects: (a) the integration of momentary sensory evidence; (b) the amount of evidence required to decide; (c) pre-stimulus presentation processes; and (d) non-evidence accumulation effects. For the present study, eight participants completed a behavioral task that required tracking the cue validity across trials and using the cue information flexibly. The task combined a reversal learning and a random dot motion discrimination task and involved three main decisions per trial: cue choice, confidence, and motion direction. After choosing one of the two possible cues (orange vs. blue), participants judged how confident (low vs. high) they were that the chosen cue will turn out to be invalid. Then, participants received a direction of motion, and subsequently, participants judged the motion direction of the random dots. The cue direction was displayed with a predetermined but unknown validity. Each participant completed a maximum of 320 trials, which were divided into informative and non-informative blocks. The interval of an informative block varied from 15-30 trials. The validity of the cue in informative blocks was set at 80% or 30%, while the validity of the cues in non-informative blocks was set at 30% for both cues. At the end of each trial, participants received rewards for their motion judgment and cue choice. The reward for the cue choice depended on the confidence reported earlier in the trial. To evaluate the validity of the estimated belief in the prior, we tested whether belief strength is associated with confidence and the true contingency. Belief strength was higher when participants reported high confidence in their cue choice ($t(7) = 5.31, p = .001$).
Furthermore, when belief strength was higher, participants chose the best cue for the block more often than when belief strength was low ($t(7) = 24.52, p < .001$). Altogether, these findings provide evidence of validity for trial-wise measures of belief strength

Continued: Seeing What You Believe: Cognitive Mechanisms of Flexible Integration of Priors in Visual Decisions

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Session:
Posters: Decision Making and Evidence-Accumulation Models

Regarding the effect of belief strength (or prior strength), the posterior estimates of the cognitive models show that the strength of belief affects various aspects of visual decision-making. When the cue was valid, stronger beliefs increased the drift rate (rate of evidence accumulation, 95% HDI = [1.09, 2.2]), increased the response bias towards the direction indicated by the cue (95% HDI = [.056, .228]), increased the threshold (amount of evidence needed to reach a decision, 95% HDI = [.019, .33]), and reduced non-decision time (secondary processes involved in the decision execution, 95% HDI = [.06, 11]). In contrast, when the cue was invalid, stronger beliefs had the opposite effects on these parameters. Overall, belief strength modulates the DDM parameters depending on the accuracy of the belief for a given trial.

The main goal of this study was to behaviorally dissociate the effect of belief on visual decision-making using trial-wise estimates of belief strength. The effects on drift rate reflect the ramping of activity in parietal regions that scale with the strength of evidence (Hanks et al., 2015). In the present study, the effect of belief strength on the drift rate is congruent with biased evidence sampling driven by post-decisional confidence (Rollwage et al., 2020).

The effects on the starting point are usually interpreted as a choice response bias (Dunovan et al., 2014; Dunovan & Wheeler, 2018). The origin of such biases in the starting point can be a result of a tendency to accept belief-congruent evidence, motor preparation (de Lange, Rahnev, Donner, & Lau, 2013), or even an increase in the sensitivity of low-level sensory representations before stimulus presentation (Kok, Failing, & de Lange, 2014). Although DDM does not dissociate between these subcomponents, it is possible to constrain them neurophysiologically (Harris & Hutcherson, 2022). Effects on the evidence accumulation threshold are associated with speed-accuracy trade-offs (Bogacz, Wagenmakers, Forstmann, & Nieuwenhuis, 2010). In the present study, we observed an effect of belief on decision threshold, suggesting that belief strength increases the amount of evidence that needs to be accumulated when the belief is congruent with visual input. This effect might be caused by a compensation mechanism to maintain high accuracy when the belief is invalid for a particular trial. The non-decision time parameter has often been neglected in the literature. Despite its marginalization, it might reflect important processes. For example, the latency of N200 potentials, which is associated with the encoding of visual stimuli, seems to track non-decision times (Nunez, Gosai, Vandekerckhove, & Srinivasan, 2019). The effect of non-decision time found in this study could emerge from the evidence-encoding onset, evidence accumulation onset, or post-decision motor execution time (Kelly, Corbett, & O'Connell, 2021). In the future, we will leverage the temporal dynamics of decision-making using neurophysiological recordings to constrain and dissociate these parameters (Harris & Hutcherson, 2022).

Cognitive and Meta-cognitive Signatures of Memory Retrieval Performance in Spoken Word Learning

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Session:
Posters: Learning

Cognitive models of memory retrieval aim to capture human learning and forgetting over time, and have been applied in learning systems that aid in memorizing information by adapting to the needs of individual learners. The effectiveness of such learning systems critically depends on their ability to use behavioral proxies to estimate the extent to which learners have successfully memorized the materials. The present study examines cognitive and meta-cognitive indicators of memory strength that are present in the learners' recorded speech signal while studying vocabulary items by vocally responding to cues. We demonstrate that meta-cognitive beliefs about memory performance are reflected in variations in pitch and speaking speed, whereas the objective accuracy of a response is mainly reflected in its loudness. The results of this study contribute to a better understanding of the relationship between prosodic speech variations and (meta)memory processes. Furthermore, they can have important implications for the further development of models of memory retrieval that are used in adaptive learning systems. For example, extracting information about a speaker's confidence from the speech signal in real time may allow for improvement of predictions of future retrieval success—without the learner having to make explicit confidence judgments after each learning trial.

Alleviating 4 Million Cold Starts in Adaptive Fact Learning

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Session:
Posters: Learning

Adaptive learning systems enable any learner to study at a level that is appropriately challenging to them. The cold start problem occurs whenever an adaptive system has not yet had the opportunity to adapt to its user or content. Using learning data from 140 thousand students, we evaluate several methods for alleviating the cold start problem in an adaptive fact learning system. We show that data-driven prediction of the learning system's adaptive parameter leads to more accurate estimates of learning at the start of a session, particularly when the prediction involves fact-specific difficulty information. The observed improvements are similar in magnitude to those in an earlier lab study, where using the predicted values as starting estimates in a learning session significantly increased posttest retention. We expect that comparable retention gains can be achieved in real-world educational practice.

Modelling the role of Hanja in the Korean mental lexicon: A second tier of spreading activation

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Session:
Posters: Perception, Cognition, Memory, Neuroscience, Language

This poster presents interim results from an ACT-R-based statistical model of a series of lexical decision experiments in Korean. The model uses two tiers of spreading activation, one of which represents semantic distance, and the other of which represents the effect of the Hanja writing system on the mental lexicon. Modelling the data requires assumptions to be made about the relationship between the tiers of spreading activation, and about the method of computing semantic association. The poster is supported by an interactive browser interface that allows participants to vary these assumptions, as well as the standard ACT-R spreading activation parameters, and explore how this impacts the model fit.

Leveraging large-scale brain connectivity data to explore and expand the common model of cognition

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Session:
Posters: Perception, Cognition, Memory, Neuroscience, Language

Over the past decades, a vast amount of models and architectures have been developed, looking at the large scale organization of the human brain on different levels of abstraction. In an attempt to synthesize the ideas from some of the most established existing models of cognitive processing, namely ACT-R, SOAR, and Sigma, the Common Model of Cognition (CMC) has been proposed. It identifies five different modules within the brain with discrete functionalites and processing connections between them, modules for Perception, Action, Long-Term Memory, Procedural Memory, as well as Working Memory. These are considered to be essential for cognition across different domains and tasks, representing a generalized model of the structuring and processing of the mind. Previous work has connected the structure of the CMC to activity in the specific brain regions, helping to validate the model and compare it to other models and architectures, like Hub-and-Spoke Architectures and Hierarchical Architectures. The CMC was found to outperform its alternatives, being a significantly better match for the experimentally gained data. However, the results also suggested that modifications to the original formulation of the CMC would improve its fit. This is not surprising, as the CMC has a rather basic structure, only incorporating high level cognitive components. Other models consist of larger networks of subcomponents, representing real human cognition more accurately. It further does not consider many significant aspects of cognitive processing like metacognition or emotional processing in the modularity and organization.

The large scale parcellation currently used to identify signals associated with each cognitive component will not be sufficient in the future, as the model grows in complexity and additional cognitive components are incorporated. Better methods are needed for identifying regions associated with specific cognitive processes and modeling these and its connections in the CMC.

To improve the identification of brain regions we can use meta-analyses of brain data. Tools like Neurosynth synthesize the results of many studies using neuroimaging, allowing to perform connectivity analyses on them. This makes it possible to relate specific brain regions to functions, as well as investigate the interactions between the different regions, which can be leveraged to inform the CMC about its structure. Due to the large amount of data and the wide variety of domains covered, meta-analyses of brain data are significantly more powerful than single studies. To validate our methods, we can use fMRI brain data from the Human Connectome Project. It provides a wide range of brain activity across multiple tasks allowing us to compare different configurations of the CMC using methods of connectivity analysis.

We propose leveraging the power of connectivity analyses with both large-scale fMRI brain data and meta-analyses of brain data to create expanded and more robust versions of the CMC. The methodology used to research this is defined as follows: First, look at shortcomings of the current CMC structure and create expanded versions with additional components integrated in a plausible way. Then identify and isolate brain activity associated with those components using the proposed combination of meta-analyses and fMRI brain data. Finally, compare the resulting predictions with the current CMC structure.

Modelling the Effects of Working Memory Demands on Accuracy Rates of Relational Reasoning Problems

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Session:
Posters: Perception, Cognition, Memory, Neuroscience, Language

Relational reasoning is a core cognitive ability necessary for intelligent behaviour as it evaluates relationships between mental representations. Laboratory-based tasks such as relational reasoning problems have long been used to investigate how individuals make inferences about such problems, with theories of mental models arguing that to solve such problems, individuals construct an integrated mental model based on the provided premises to generate or verify conclusions. Computational models of relational reasoning offer insights into how individuals generate such mental models and why some cognitive strategies may be preferred over others. However, many of these models do not directly account for what is often cited as a primary reason for the difficulty of different problems, the effects of increased working memory demand. In this paper, we present four ACT-R models that simulate the negative relationship between accuracy rates and relational problem complexity and demonstrate how different memory errors of omission and commission can account for qualitatively different reasoning processes. Our cognitive models demonstrate the importance of future work to consider individual differences in working memory processing, micro-strategy preferences, and the effects of different memory errors on the reasoning process.

An ACT-R Observer Model for Anticipatory Assistive Robots

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Session:
Posters: AI and ACT-R

Interactions between human users and assistive robotic systems in real life often involve both cognitive and physical interactions. In order to support humans well in their daily life, a robotic agent needs to be aware of the situation, anticipate the human agent, and generate human-like behaviors. In this work, we present an ACT-R observer model as a possible implementation on the robotic agent's cognitive level. The model anticipates the human agent's behaviors in an application example: a tea-making task. We discuss how such a model provides us the possibility to connect cognitive and physical human-robot interactions, and the advantages of such a model compared with common state-of-the-art approaches for human intention and behavior predictions. We also discuss how such an individual ACT-R model provides potential for an anticipatory, situation-aware robotic agent in real life applications, allowing us to solve ambiguities from acquiring input via various sensors and gain time for proactive support.

Modeling A Human-AI Cooperation Task In ACT-R

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Session:
Posters: AI and ACT-R

How can we model the ways race-based systems of power and oppression impact the ways people interact with AI agents? To approach this question, we are developing a computational model of a human-AI interaction study that explores the impact of racialization on such interactions. We're developing an ACT-R model that connects with the existing study infrastructure and code to complete the Pig Chase task (a modified version of the Stag hunt task) using NodeJS. Connecting the existing Pig Chase Environment to ACT-R provides us with an opportunity to understand and in turn lay out the process of recognizing the steps taken to make certain decisions, particularly without creating another environment, something that can be especially time consuming for the computational cognitive modeling process. To develop a more complete simulation of related human behavior with greater resolution, we are developing a connection between ConceptNet and ACT-R. Integrating it with our model will provide the model with existing historical and sociocultural perspectives and provides us with a more realistic ability to understand the interaction between the user and the environment after it has the knowledge of the race of the AI agent.

Enabling Human-Machine Symbiosis: Automated Establishment of Common Ground and Estimates of the Topological Structures of Commander's Intent

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Session:
Posters: AI and ACT-R

As recent advances in artificial intelligence (AI) and machine learning (ML) have failed to slow as predicted, there has been an unprecedented increase in the adoption of these methods for complex domain problems and settings far removed from computer science and engineering concerns. As these technologies mature, especially in the area of neuro-symbolic intelligence, interest has increased in the development of artificial cognitive capabilities that would allow these new systems to act less like an automated appliance and more like an interdependent teammate. Department of Defense goals for automation call for a dramatic increase in autonomous systems to support mission goals in ways that do not require additional human teammates to manage, control, and operate these resources. These goals are currently unobtainable due to the high cognitive loads associated with most AI- and ML-based decision support systems. Next-generation AI systems need to support symbiotic, human-centered processes, including objective alignment, trust calibration, common ground, and the ability to build complex workflows that manage risks due to resources such as time, environmental constraints, and diverse computational settings from super computers to edge devices and autonomous systems.

In this paper we introduce a novel formalism to represent the common ground shared between co-performers, whether humans or machines, and a formal procedure for the establishment of this common ground using conceptual pacts of both quantitative and qualitative natures, resulting in machine representations of human assumptions, goals, and value judgements on the shared environment, representing elements of Commander's Intent. We further extend this process by using self-organizing maps to efficiently estimate the topological structure underlying Commander's Intent allowing machine co-performers to come to common operational understandings of shared environments and mission goals, demonstrated over several datasets drawn from diverse domain applications.

Embodied communication model in ACT-R based robot

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Session:
Posters: AI and ACT-R

Human communication is mediated by symbolic (e.g., language) or quantitative (e.g., body movements) representations. For smooth interaction between humans and machines, it is important for machines to have a mechanism to convert between symbolic and quantitative representations. In this study, we construct a model in which the cognitive architecture as a symbol processing system and the robot as an embodied media interact with each other. In this model, we use a simple word game with a human as a test case of communication. The conversion from a symbolic to a quantitative representation in this model corresponds to the robot's posture based on the "size image" of a noun. The "size image" is a general human image of a word taken from the word distributional representation. The influence of quantitative representation on symbols in this model is represented by the influence of the robot's posture on the model's next word selection.

GPT-Jass : A Text-to-model Pipeline for ACT-R Models

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Session:
Posters: AI and ACT-R

The GPT-family of Large Language Models has garnered significant attention in the past year. Its ability to digest natural language has opened up previously unsolvable natural language problem domains. We tasked GPT-3 with generating complex cognitive models from plain text instructions. The quality of the generated models is dependent upon the quality and quantity of fine-tuning samples, but is otherwise quite promising, producing executable and correct models in four of six task areas.

A Structural Model of Existential Certainty and Relativistic Beliefs Predicting Peer Competence of Stimulant Users

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Session:
Posters: Applied and Meta-Science

We tend to make judgments of our peers in many ways, including their level of competence, and we are more likely to interact with those who we have judged as competent (Fiske, 2007). Such judgments may partly be affected by cognitive factors within us, such as our internal control or our quest for knowledge, and it is possible that our judgments might also be attenuated by the extent to which we believe that absolute truth and morality is subjective (Forsyth, 1980).

The present study hypothesized a structural model to evaluate the above ideas. The outcome variable of judged peer competency was a measured variable using the competency scale. Cognitive factors was the latent predictor variable indicated by need for cognition, symbolic immortality, and internalized control. Holding relativistic beliefs was the measured mediator variable based on the relativism subscale. Inventories were completed by 193 undergraduate at California State University, Sacramento students.

The chi-square value for model fit was not statistically significant, $8.105(4, N = 193), p = .08$, and most of the other indexes also suggested a good fit: $GFI = .98, NFI = .93, CFI = .96, RMSEA = .07$. Of the three paths, only two were statistically significant. The path from abstract definitions to perceptions of peer competence was not significant, but the paths from our cognitive factor to relativistic beliefs (path coefficient = -.18) and the path from relativistic beliefs to perceptions of peer competence (path coefficient = .18) were each significant, with approximately 18% of the variance in perceptions of peer competence explained.

Because the direct path path from our cognitive factor to perceptions of peer competency was not significant in the mediated model, there was the possibility that mediation might have been obtained. We evaluated that by evaluating the unmediated model. However, in the unmediated model the direct path from the cognitive factor to perceptions of peer competency was not statistically significant (path coefficient = -.03). It therefore appears that our cognitive factor was not directly related to perceived peer competency, but did act through relativistic beliefs in affecting judged peer competence.

Cognitive Modelling of Intention Recognition in Cocktail Mixing

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Session:
Posters: Applied and Meta-Science

Recognising the intention of a human partner is a key challenge for collaborative systems in human-robot interaction. However, existing studies of intention recognition abilities in AI system mostly focus on data-driven approaches and the recognition of direct action intentions (low-level intentions). We propose an artificial intention recognition approach that is implemented as a cognitive model in the theory-based ACT-R architecture and that infers superordinate action goals (high-level goals). We tested our approach for the recognition of cocktails from mixing sequences performed by human participants in an experimental study. Intention recognition speed of the model was evaluated and compared to human intention recognition performance. Our results indicate that the implemented model successfully recognises high-level intentions and tends to be substantially faster than humans.

Using cognitive models to test interventions against mind-wandering during driving

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Session:
Posters: Applied and Meta-Science

In this study, we contrasted six different models to show the effects of different interventions by adaptive systems designed to prevent mind-wandering while driving. Although cognitive load associated with secondary tasks tends to affect driving negatively (e.g., Unni et al., 2017; Salvucci & Macuga, 2002; Ito et al., 2001), sometimes a simple secondary task can improve driving performance when the situation is mundane (e.g., Engström et al., 2017; Nijboer et al., 2016). Nijboer and colleagues (2016) have hypothesized that if the driving task is simple, people might start mind wandering, which interferes with driving (Yanko & Spalek, 2013, 2014; Martens & Brouwer, 2013). A simple secondary task, which imposes less workload than mind-wandering, could prevent this from happening. Automation system that adapt to the cognitive state of the driver could leverage this effect by inducing mild cognitive load during mundane driving scenarios with the goal to improve driving performance. To test suitable interventions, we combined an existing driver model (Salvucci, 2006) with an existing model of mind wandering in the cognitive architecture ACT-R (van Vugt et al., 2015) and tested different interventions that impose cognitive workload in different amounts during specific times of the simulation. Using these different models we, firstly, show how mind-wandering harms driving performance, secondly, show that mild cognitive load can mitigate this effect and, lastly, show that adapting to the cognitive state of the model incurs a significant processing cost that adaptive automation systems have to account for.

Predicting Human Interleaving Time in Semi-Automated Vehicles

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Session:
Posters: Applied and Meta-Science

We present the first steps towards a processing model to understand transitions of control in semi-automated vehicles. In a transition of control, a human takes over the control from a (semi-) automated vehicle. Based on a recent theoretical model, we describe this process as interruption handling. In an interruption handling process, various distinct processing steps can be identified. We then take the data from a recent meta-review on transitions of control to map response times to specific processing stages of interruption handling. We then estimate the response time distribution for each stage. The model can then be used to identify what response distributions might look like for different scenarios, such as different alert modalities. Initial findings highlight how for example bi-modal alerts mostly speed-up initial processes of the interruption handling, but later processes less so.

Reasoning and logic—a Piagetian perspective

Winstanley, M. A.

Session:
Posters: Applied and Meta-Science

According to Jean Piaget, intelligence has its roots in the self-regulation of organisms and, unfolding in a sequence of stages, bears fruit in the hypothetico-deductive reasoning of homo sapiens. In a nutshell, this poster sets out Piaget's psychological theory of hypothetico-deductive reasoning and clarifies its relationship with propositional logic by elaborating on Piaget's own intimations.

Piaget typically discerned four stages—sensorimotor, semiotic, concrete- and formal-operational—in the sequential development of intelligence. At the fourth stage, reasoning is propositional and hypothetico-deductive, and 'interpropositional grouping' is the term Piaget coined for the cognitive structure characterising this stage of cognitive development.

Axiom schemata traditionally describe propositional calculus; according to Piaget, 'logic is the axiomatic of the operatory structures whose real functioning the psychology and sociology of thought study.' Elaborating Piaget's claim, I, first, show that the interpropositional grouping is structurally equivalent to a Boolean algebra. I, then, illustrate how the identities characterising a Boolean algebra follow rigorously from a version of the Russell-Bernays axiom schema for propositional logic. Finally, I indicate how the interpropositional grouping serves as the source for logicians like Russell and Bernays to construct axiom schemata. In particular, I argue that the Russell-Bernays axiom schema represents a compact synopsis of the element of the interpropositional grouping that corresponds to the unit element of a Boolean algebra.

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Acknowledgements

We owe a debt of gratitude to Leonhard Volz for all his hard work maintaining and organizing the conference website. There were a number of additional local organizers that helped with finalizing conference materials, including this booklet; specifically, we thank Simon Kucharský, František Bartoš, Pelin Özsezer, and Kianté Fernandez. In addition to the names mentioned above, additional help at the registration desk and on campus was provided by Konradas Mikalauskas, Madlen Hoffstadt, Anne Giacobello, Henrik Godmann, and Lucija Blaževski. Emily Gale at the University of Amsterdam's Conference and Event Planning is thanked for the professional help in organizing catering, booking venues, planning security, obtaining signs, and other logistics.

mathpsych.org was created by Alex Konetchy and Joachim Vandekerckhove. This document is based on a template by Maxime Lucas. Source code for the template can be found at github.com/maximelucas/AMCOS_booklet. The background picture from the booklet cover was designed by Jon Phillips.

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The MathPsych / ICCM / EMPG 2023 conference is sponsored by the Netherlands Organization for Scientific Resesearch (NWO), Elsevier, and Springer.

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