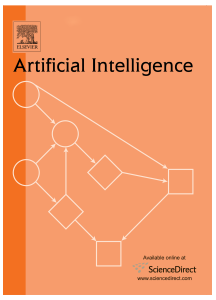
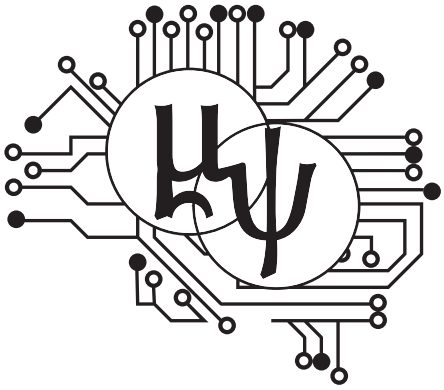
MathPsych 2017 ICCM





Welcome

Dear Colleague:

We are happy to welcome you to MathPsych/ICCM 2017, which combines the 50th Annual Meeting of the Society for Mathematical Psychology, the European Mathematical Psychology Group meeting, and the 15th Meeting of the International Conference on Cognitive Modelling. Hosted by the University of Warwick, this year's conference runs from July 22 to 25, and will feature keynote addresses from Peter Dayan, Joseph Houpt (2016 winner of the William K. Estes Early Career Award), and Randy Gallistel. There are also four invited symposia with a total of 25 talks, 142 contributed talks, and more than 70 posters. On the tutorial and workshop day, there are five tutorials, including a professional development symposium hosted by the Women of Mathematical Psychology. This combined conference has attracted more than 270 participants.

We would like to acknowledge the Society for Mathematical Psychology (SMP), Behavioural Sciences at the University of Warwick, the Artificial Intelligence Journal, and the US Army Research Laboratory and Army Research Office, whose generous support kept the conference fees low and allowed us to fund a large number of student awards. We also would like to acknowledge the people who brought these conferences all together for the first time (Andrew Heathcote, Amy Criss, Frank Ritter, David Reitter, and Matthias Gondan), the hard work of the officers of the SMP (Brent Miller, Leslie Blaha, Richard Golden, and Scott Brown), Jelmer Borst for creating the poster, University of Warwick staff for making the conference tax exempt (Steve McGaldrigan and Jonathan Pearce), the help of Warwick PhD students on many key aspects of the conference (Alexandra Surdina, Jake Spicer, Mengran Wang, and Jianqiao Zhu).

Best,

Adam Sanborn, Gordon Brown, and James Adelman (MathPsych co-chairs)

Marieke Van Vugt, Adrian Banks, William Kennedy (ICCM co-chairs)

General Information

The University of Warwick is located in the heart of England, 3 miles (5 km) from the centre of Coventry, on the border with Warwickshire. The conference will be held at the Scarman Conference Centre at the University and in the brand-new Slate building across the street from Scarman (postcode for both is CV4 7SH). The tutorials will take place in the Tiered Lecture Theatre, and Spaces 41 and 43 of Scarman, and the welcoming reception will take place in the lounge at Scarman. The MathPsych tracks of the main conference will take place in Spaces 41 and 43 in Scarman as well as in the Slate. The ICCM tracks will take place in the Tiered Lecture Theatre of Scarman. All plenary talks, the poster session, and lunches will take place in the Slate. Refreshments during coffee breaks will be available both in the lounge of Scarman and in the Slate.

Welcome Reception

The welcome reception will be held July 22nd in the Scarman and will held from 6:00pm to 8:00pm. There will be canapés and complimentary drinks.

Registration Desk

The registration desk will be set up in the lobby of the Scarman Conference Centre, and volunteers will be present at all times to register attendees and answer questions.

Catering, Lunch, & Coffee breaks

As part of the registration, we offer a lunch buffet to all attendees on all days of the conference, several coffee breaks each day with snacks and refreshments, and coffee on arrival from 8:30am.

Participants who booked rooms at Scarman or Arden during registration are entitled to breakfast each morning at their hotel. For the same participants, dinner is included each night except for the night of the conference banquet. For those staying at both Scarman and Arden dinners will be at the Lakeside Restaurant in Scarman.

For those not staying at Scarman or Arden, dinner can be purchased at Scarman outside of the conference booking, though the restaurant has limited capacity. There are also a variety of other on-campus eateries (http://www2.warwick.ac.uk/services/retail/eat-drink) and the Varsity Pub is within easy walking distance (https://www.greatukpubs.co.uk/varsitywarwick). Further afield, there are many good restaurants in Coventry, Kenilworth, Leamington Spa, and Warwick.

Internet

You can use the “Warwick Guest” wireless network anywhere on campus. Details here: http://www2.warwick.ac.uk/services/its/servicessupport/networkservices/wifi/how/warwick-guest/. If you have any problems accessing the internet, the reception desk at Scarman can help. If using Twitter, please use the hashtag **#iccmpsyched** to discuss the conference.

Conference Banquet

The conference dinner will be held the evening of July 24th. At 7:00pm, chartered coach transportation will leave from Scarman to Warwick Castle. Reception drinks will be held in the State Rooms, followed by a three-course dinner in the state dining room and the 17th century Great Hall. Return transportation will leave the castle at approximately 11pm.

Vegetarian, gluten-free, and dairy-free meals are available only to participants who requested them in the pre-conference survey. To claim your pre-booked meal, please tell your server your name and dietary requirements when you have been seated.

Travel

If you are travelling internationally, the nearest major airport is Birmingham International (11 miles / 18 kilometres away) and there are various ways to travel to the university from there: http://www2.warwick.ac.uk/about/visiting/directions/international/.

If you are travelling within the UK, the university can also be accessed by car, train, or bus: http://www2.warwick.ac.uk/about/visiting/directions/.

Parking is included in the conference registration and is available at Scarman.

Transportation to the Cognitive Science conference

While making travel plans, please note that we offer coach transportation direct to the Cognitive Science conference hotel at the conclusion of MathPsych/ICCM 2017. There is no fee for the coach. Tickets will be given upon registration to participants who indicated that they would like tickets in the pre-conference survey. All other participants can request tickets from the Registration Desk on a first-come-first-served basis.

Abstracts and ICCM Proceedings

No printed abstract booklets will be distributed at the conference. Instead, the 2017 conference has a smartphone app through Eventor. First download and install Eventor from Google Play or the App Store onto your mobile device. Then either search for the conference name within Eventor, or use the app's QR code scanner to scan the QR code to the right. Note that only talk abstracts were able to be included in the app, poster abstracts are available in the PDF linked below.

If you wish to have a hard copy, there is a printable PDF file of the abstracts: http://mathpsych.org/conferences/2017/file/MP_ICCM2017_Abstract_Booklet.pdf

The ICCM proceedings are available here: http://iccm-conference.org/2017/

Presentation Guidelines

Tutorials

There will be five tutorials on July 22nd: "Building cognition from spiking neurons: Nengo and the neural engineering framework" by Terrence C. Stewart and Chris Eliasmith, "A practical introduction to distributed collaboration for formal modelling" by Andy Wills, Charlotte E. R. Edmunds, Kenneth J. Kurtz, and Garrett Honke, "Practical advice on how to run human behavioral studies", by Frank E. Ritter, "Advances in data collection and analysis of card sorting data" by Simon J. Blanchard, and "CV and Resume Writing Workshop" hosted by Women of Mathematical Psychology. Details are here: http://mathpsych.org/conferences/2017/tutorials/.

Talks

There will be four parallel talk sessions in the Slate, the Tiered Lecture Theatre (Scarman), Space 41 (Scarman), and Space 43 (Scarman), consisting of strict 20-minute slots for every talk (15 min. talk + 5 min. for discussion). It is essential to stick to timing so everyone can switch sessions in order to hear specific talks. Symposium talks are on the same schedule. Each session will be chaired by the last speaker in the session. Please load your presentation onto the computer or test your own computer well before the session starts. There will be Conference Assistants on hand between sessions in case of any IT issues.

Plenary Speakers

The plenary on July 23rd (Peter Dayan) will be preceded by welcoming remarks, the plenary on July 24th (Joseph Houpt) will be preceded by a short awards presentation, and the plenary on July 25th (Randy Gallistel) will be preceded by a few words about Ragnar Steingrimsson. Plenary addresses will be at 1:10pm in the Slate.

Invited Symposia

There are four invited symposia: "Models of decision from experience" (Chair: Ido Erev) on July 23rd in the Slate, "Using cognitive models to inform neuroimaging data (and vice versa!)" (Chair: Jelmer Borst) on July 23rd in the Tiered Lecture Theatre (Scarman), "Advances in distributional models of language and meaning" (Chairs: John Willits and Melody Dye) on July 24th in the Slate, and "Bridging levels of analysis with rational process models" (Chairs: Tom Griffiths and Adam Sanborn) on July 25th in the Slate.

Posters

The posters will be on display on July 23rd from 5:30pm to 8:00pm in the Slate, and the poster session will take place from 6:00pm to 8:00pm. The name of the first author will be displayed on each poster board. Posters can be up to A0 in size. If the poster is A0 sized, it is recommended it be in portrait orientation, as it will slightly overhang the board in landscape orientation. A1 sized posters will easily fit in either portrait or landscape orientation. There will be canapés and complimentary drinks at the poster session. A Poster Award will be given to the poster which receives the greatest number of votes from attendees. Attendees can vote using the ballots distributed during registration, depositing them in the ballot box during the poster session.

SATURDAY July 22nd, 2017

Time	Tiered Lecture Theatre (Scarman)	Space 41 (Scarman)	Space 43 (Scarman)
9:00 AM	**Practical advice on how to run human behavioral studies** Frank E. Ritter	**Building cognition from spiking neurons: Nengo and the neural engineering framework** Terrence C. Stewart and Chris Eliasmith	**A practical introduction to distributed collaboration for formal modelling** Andy Wills, Charlotte E. R. Edmunds, Kenneth J. Kurtz, and Garrett Honke
12:00-1:30 PM		Lunch	
1:30-4:30 PM	Women of Mathematical Psychology Professional Development Symposium: **CV and resume writing workshop** Keynote speaker: Carolyn Cramer	**Building cognition from spiking neurons: Nengo and the neural engineering framework** Terrence C. Stewart and Chris Eliasmith	**Advances in data collection and analysis of card sorting data** Simon J. Blanchard

Time	Lounge (Scarman)
6:00 - 8:00 PM	**Welcoming Reception**

SUNDAY July 23rd, 2017

Time	Slate	Space 41 (Scarman)	Space 43 (Scarman)	Tiered Lecture Theatre (Scarman)
8:30 AM		Welcoming Refreshments (Scarman)		
9:00 AM	**Models of Decisions from Experience Symposium** **Gonzalez**: Some things that glitter are gold: A Shiny app for an Instance-Based Learning model	**Response Times** **Ratcliff**: Modeling decision processes on a continuous scale	**Hypothesis Testing** **Spektor**: You can't make a silk purse of a sow's ear: On the relative merit of empirical priors in reinforcement learning models	**Language** **Matzig**: A computational investigation of sources of variability in sentence comprehension difficulty in aphasia
9:20 AM	**Ludvig**: Modeling memory biases in decisions from experience	**Gondan**: Foundations of response time measurement	**van Ravenzwaaij**: A simulation study of the strength of evidence in the recommendation of medications based on two trials with statistically significant results	**Lindes**: Ambiguity resolution in a cognitive model of language comprehension
9:40 AM	**Denrell**: Learning from experiences with missing feedback	**Van Zandt**: Hierarchical hidden Markov models for response time data	**Golden**: Identifying probability modeling flaws using generalized information matrix tests	**Vasishth**: Feature overwriting as a finite mixture process: Evidence from comprehension data
10:00 AM	**Plonsky**: The wavy recency effect of rare events and learning in different experimental settings	**Blaha**: A motor preparation model account of simple one-choice reaction times	**Myung**: Robust Adaptive Design Optimization	**Morita**: Implicit memory processing in the formation of a shared communication system
10: 20 AM		Coffee Break (Slate and Scarman)		
10:40 AM	**Models of Decisions from Experience Symposium** **Pleskac**: Modeling adaptive exploration in decisions from experience: A sequential sampling approach	**Neuroscience** **Q. Zhang**: Neural evidence of insertion and subtraction of information processing stages	**Visual Memory** **P. Smith**: The power law of visual working memory characterizes attention engagement	**Emotion** **van Vugt**: How does rumination impact cognition? A first mechanistic model
11:00 AM	**Usher**: The impact of presentation/evaluation format on preference formation and risk biases	**Bahg**: Implementation of Adaptive Design Optimization in functional MRI experiments	**Lerch**: Visual working memory for dynamic human movement: A normative computational account	**Dancy**: A computational cognitive-affective model of decision-making
11:20 AM	**Tsetsos**: Rapid experiential decisions as a window to paradoxical multiattribute and risky choice patterns	**Nunez**: Model-based cognitive neuroscience for the chronometry of simple human decision making	**Donkin**: Hierarchical Bayesian cognitive model-based meta-analysis	**Petters**: A new direction for attachment modelling: Simulating Q set descriptors
11:40 AM	**Erev**: Different choice environments affect recency patterns not preferences	**Teodorescu**: A neurally plausible model for generating probability estimations from a quantum decision making model	**Cowell**: A hierarchical Bayesian approach to state trace analysis with application to implicit visual memory	**Moye**: A computational model of focused attention meditation and its transfer to a sustained attention task
12:00 PM		Lunch Buffet (Slate) and SMP meeting (TBD)		
1:10 PM	**Peter Dayan:** Betwixt fast and slow: Integrating model-free and model-based decision-making			(Slate)
2:20 PM		Coffee Break (Slate and Scarman)		
2:40 PM	**Response Times** **Heathcote**: Balancing the evidence on "don't know" and confidence judgments	**Decision Making** **Gluck**: Inferring decision strategy: Explorations in integrating multiple sources of behavioral data	**Memory** **Folkerts**: Human episodic memory retrieval is accompanied by a neural jump back in time	**Neuroscience Symposium** **Dotlacil**: Building an ACT-R reader for eye-tracking corpus data
3:00 PM	**Mallahi-Karai**: The box model - a dynamic stochastic approach for decision making with n alternatives	**Schramm:** A Thurstonian investigation into the relationship between probabilistic and temporal discounting	**Huber**: Episodic memory and spatial navigation in the medial temporal lobe	**Anders**: Data-driven process models and brain-lesion data: How patient-based analyses can inform us about interference and cognitive control
3:20 PM	**Kirkpatrick**: Constraining computational models of decision-making with equal-evidence perceptual tasks	**Haines:** Linking emotion to decision making through model-based facial expression analysis	**Weidemann**: Using neural data and machine learning to distinguish between models of recognition memory	**Anderson**: Combining space and time in the mind
3:40 PM	**Trueblood**: The impact of the strength and duration of early information on perceptual decision-making	**Steingroever:** Modeling individual and developmental differences of strategy use in decision-making tasks – A Bayesian hierarchical approach	**Howard**: Toward a unified mathematical model of episodic memory	**van Maanen**: Understanding the dynamics of decision boundaries in the brain
4:00 PM		Coffee Break (Slate and Scarman)		
4:20 PM	**Multi-alternative Decision Making** **Gluth**: Multi-alternative decision making is affected by value-based attentional capture	**Processing Tree Models** **Heck:** Modeling mouse-tracking trajectories with generalized processing tree models	**Intertemporal Choice** **Dai**: Are intertemporal preferences transitive? A Bayesian analysis of repeated individual intertemporal choices	**Neuroscience Symposium** **Stocco**: Using effective connectivity to test computational cognitive models: It's models all the way down (and it's a good thing!)
4:40 PM	**Noguchi**: Multialternative decision by sampling	**Schweickert:** Tree inference: Factors selectively influencing processes in multinomial processing trees with response times	**Liu**: Informing cognitive models of self-control and impulsivity in intertemporal choice	**Turner**: A model for the neural and mechanistic basis of self control
5:00 PM	**Tsetsos**: Context-sensitive valuation during simple multi-alternative decisions		**Ahn**: Pushing the limits of Precision Medicine: Use of Bayesian adaptive design optimization leads to highly rapid, precise, and reliable estimates of delay discounting rates	**Borst**: Using large-scale spiking neural networks to simulate MEG data of associative recognition
6:00 - 8:00 PM		Poster session (Slate) Cast your vote for the Poster Award		

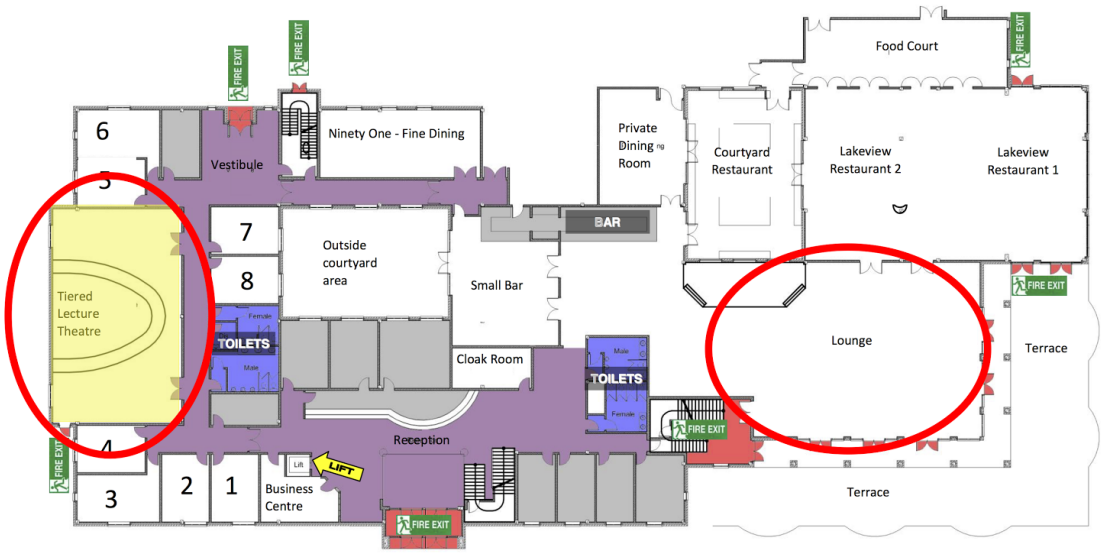
MONDAY July 24th, 2017

Time	Slate	Space 41 (Scarman)	Space 43 (Scarman)	Tiered Lecture Theatre (Scarman)
8:30 AM		Welcoming Refreshments (Scarman)		
9:00 AM	**Context / Advances in Distribution Models of Language and Meaning Syposium** **Gronchi:** Context-driven effects in perception and cognition: a variational approach	**Categorization and Instance Based Learning** **Ransom**: "Is this a Dax I see before me?": the effects of sample selection and sample size on generalization and categorization	**Decision Making** **Hancock**: Improving Decision Field Theory for consumer choice modelling applications	**Neuroscience** **T. Stewart**: Analysis of a common neural component for finger gnosis and magnitude comparison
9:20 AM	**Yim:** Modeling word learning through context	**Austerweil**: Uncovering unsupervised categorization biases using Markov chain Monte Carlo with People	**Glickman**: Using eye trajectories to understand preference formation of risky choices	**Shein**: Parameter exploration of a neural model of state transition probabilities in model-based reinforcement learning
9:40 AM	**Dye**: The importance of word order in the distributional construction of meaning	**Chrabaszcz**: IBL-Bayes: A Bayesian Implementation of the Instance-Based Learning model of choice	**Walasek**: Challenges in estimating loss aversion using accept-reject tasks	**Stocco**: Basal Ganglia-inspired functional constraints improve the robustness of Q-value estimates in model-free reinforcement learning
10:00 AM	**Reitter**: Connectionnist language models as models of human language expectations: Learning Simpler Language Models with the Delta Recurrent Neural Network Framework	**Blurton**: A Poisson random walk model for response times in multi-alternative categorization	**N. Stewart**: Psychological parameters have units: A bug fix for stochastic prospect theory and other decision models	**Rosenbloom**: Toward a neural-symbolic Sigma: Introducing neural network learning
10: 20 AM		Coffee Break (Slate and Scarman)		
10:40 AM	**Advances in Distribution Models of Language and Meaning Syposium** **Hoffman**: Concepts, control and context: A connectionist account of normal and disordered semantic cognition	**Hypothesis Testing and Fallacies** **Miller**: Computing Bayes factors via thermodynamic integration with an application using the Linear Ballistic Accumulator model	**Agents and Heuristics** **Konovalova**: Selective information sampling and the in-group heterogeneity effect	**Neuroscience** **Zajkowski**: A causal role for right frontopolar cortex in directed, but not random, exploration
11:00 AM	**Pearl**: Integrating conceptual and syntactic information to understand the development of English verb classes	**Gronau**: Warp-III sampling for comparing complex cognitive models	**Lewandowsky**: Scientific facts versus the public's rational rejection of evidence	**Cutsuridis**: A neural accumulator model of antisaccade performance of healthy controls and obsessive-compulsive disorder patients
11:20 AM	**Keuleers**: Predicting item-level effects of relatedness with models based on prediction and counting	**Charles-Cadogan**: A weak harmonic transitivity axiom	**Kvam**: The evolution of optimal and heuristic strategies for sequential sampling	**Caso**: A neurocomputational model of learning to select actions
11:40 AM	**Willits**: A two-stage model of the development of semantic categories	**Yearsley**: A Quantum Theory account of order effects and conjunction fallacies in political judgments	**Luan**: The wisdom of select cues	**Sloman**: Gaps between human and artificial mathematics
12:00 PM		Lunch Buffet (Slate) and JMP meeting (TBD)		
1:10 PM		**Joseph Houpt:** Toward a cognitive modeling Rosetta Stone (Slate)		
2:20 PM		Coffee Break (Slate and Scarman)		
2:40 PM	**Hypothesis Testing** **Kennedy**: Not every credible interval is credible: Evaluating robustness in the presence of contamination in Bayesian data analysis	**Multi-attribute Decision Making** **Zhao:** Low dimensional representations in multi-cue judgement	**Cognitive Ability** **Schweizer**: Modeling cognitive abilities in considering effects due to item-position and processing speed	**Reasoning** **Costello**: Noisy reasoning: A model of probability estimation and inferential judgment
3:00 PM	**Segert**: Some theoretical issues regarding the use of Bayes factors for cognitive models	**Bhatia:** Object representation in multiattribute choice	**S. Brown**: Using cognitive modelling to better understand the heritability of cognition	**Ragni**: Cognitive computational models for conditional reasoning
3:20 PM	**van Doorn**: Using data augmentation to enable nonparametric Bayesian hypothesis testing	**Mullet:** Modelling moment to moment attention bias in multi attribute choice	**Rieskamp**: Preference shifts or more errors: How increased cognitive load changes decision making	**Ragni**: Beyond the visual impedance effect
3:40 PM	**Chechile**: A Bayesian approach for the Wilcoxon signed-rank statistic	**Hawkins:** A unidimensional representation of value drives preferences for most- and least-favored options	**Alexander**: Metric based Cultural Consensus Theory	**Prezenski**: Implementing mental model updating in ACT-R
4:00 PM		Coffee Break (Slate and Scarman)		
4:20 PM	**Stopping and Response Times** **Palestro**: Revisiting the decision boundary debate	**Categorization** **Albrecht:** Explaining multiple cue judgment with a mixture model that combines exemplar with cue abstraction processes	**Noise in Cognition and Representation** **Surdina**: Noisy morals: Variability of moral value judgments in a constant environment	**Decision Making** **Wong**: Sequential search behavior changes according to distribution shape despite having a rank-based goal
4:40 PM	**Voss**: Sequential sampling models with variable boundaries and non-normal noise: A comparison of six models	**Hoffmann:** Integrating cue abstraction with retrieval from memory: A learning approach	**Wilson**: What is the nature of decision noise in random exploration?	**Sharma**: Decisions from experience: Modeling choices due to variation in sampling strategies
5:00 PM	**Fific**: A race model for multiple stopping rules in decision making	**Speekenbrink:** Estimating and testing intra-individual multiple-systems and -process models	**J. Zhang**: Subset System: Mathematical foundation for relational semantics	**Polakow**: Quantum entanglement, weak measurements and the conjunction and disjunction fallacies
5:40 - 6:40 PM		SMP Business Meeting - all welcome (Slate) Student Participation Awards will be distributed		
7:00 PM		Coach to Banquet at Warwick Castle		

TUESDAY July 25th, 2017

Time	Slate	Space 41 (Scarman)	Space 43 (Scarman)	Tiered Lecture Theatre (Scarman)
8:30 AM		Welcoming Refreshments (Scarman)		
9:00 AM	**Probabilistic Models / Rational Process Models Symposium** **Kalm:** Recency-weighted incremental learning	**Memory** **Caplan**: A challenge to the independent-cueing assumption: backward serial recall of chunked lists	**Representation** **Basieva**: Lindblad equation in quantum-like models of decision making in different contexts	**Human Performance and Visual Cognition** **J. Smith**: Data informed cognitive modelling of offshore emergency egress behaviour
9:20 AM	**Chater:** A nearly universal, but very slow, "blank slate" learning algorithm for inverse inference	**Zemla**: Estimating semantic networks from fluency data	**Busemeyer**: Hilbert space multi-dimensional modeling	**Osterloh**: Modelling workload of a virtual driver
9:40 AM	**Singmann:** Belief revision by learning indicative conditionals: selecting among doubly Bayesian models using Bayes factors	**Hemmer**: Evaluating the role of prior knowledge and random guessing in long-term memory	**Seri**: Measuring the utility for money in a riskless context: evidence on separable representations	**Wortelen**: Comparing the input validity of model-based visual attention predictions based on presenting exemplary situations either as videos or static images
10:00 AM	**Lieder**: Resource-rational analysis	**Dennis**: A hierarchical Bayesian model of memory for when based on Experience Sampling data	**Dzhafarov**: Canonical systems of random variables in contextuality analysis	**Lindner**: Modeling of visual search and influence of item similarity
10: 20 AM		Coffee Break (Slate and Scarman)		
10:40 AM	**Rational Process Models Symposium** **Dasgupta**: Stochastic hypothesis generation in human probabilistic inference	**Decision Making** **Luckman**: Lotteries versus investments: Exploring effects of financial framing on response times in risky choice.	**Stop-signal / Systems Factorial** **Matzke**: The lognormal-race model of response inhibition: A simple process model of performance in the stop-signal paradigm	**Artificial Systems** **St Amant**: Spatial relationships and fuzzy methods: Experimentation and modeling
11:00 AM	**Zhu**: Mental sampling in multimodal representations	**Davis-Stober**: A large-scale study examining differences in risk attitude across three choice contexts: financial choices, health care choices, and climate change policies	**Colonius**: Stop signal modeling revisited	**Yuan**: Generating random sequences for you: Modeling subjective randomness in competitive games
11:20 AM	**K. Smith**: Efficient physical cognition relies on both approximate simulation and sampling	**Regenwetter**: A context-dependent random preference approach to the description-experience gap	**Eidels**: Survivor interaction contrasts for error response times – part 1: Non-parametric contrasts for serial and parallel systems	**Stearns**: Applying Primitive Elements Theory for procedural transfer in Soar
11:40 AM	**Hamrick**: Adaptive allocation of resources for mental simulation		**Townsend**: Survivor interaction contrasts for error response times – part 2: Theorems for Poisson race models, diffusion models, and initial data	
12:00 PM		Lunch Buffet (Slate)		
1:10 PM	**Randy Gallistel**: Information Theory and stochastic model selection in associative learning and memory			(Slate)
2:20 PM		Coffee Break (Slate and Scarman)		
2:40 PM	**Response Times** **Malhotra**: Distinguishing between evidence accumulation and temporal probability summation in perceptual decision making	**Rationality** **Analytis:** Make-or-break: chasing risky goals or settling for safe rewards?	**Knowledge Space Theory and Choice** **Heller**: Knowledge space theory for polytomous items	**Language** **Tessler**: Warm (for winter): Comparison class understanding in vague language
3:00 PM	**Weichart**: A dynamic conflict-based account of intra-trial decision-making	**Sims:** Efficient coding predicts the universal law of generalization	**Stefanutti**: On the generalization of knowledge space theory to polytomous items	**Kelly**: Degrees of separation in semantic and syntactic relationships
3:20 PM	**Andrews**: A hierarchical diffusion model analysis of the Approximate Number System	**Stojic:** Trials-with-fewer-errors: Feature-based learning and exploration	**Noventa**: A possible connection between Knowledge Space Theory and Item Response Theory using Information Theory	**Cole**: Linking memory activation and word adoption in social language use via rational analysis
3:40 PM	**Holmes**: Evidence accumulation versus urgency gating: what's the distinction?	**Melkonyan:** Virtual bargaining: A mathematical theory of social interaction	**Wollschlaeger:** The (simple) 2N-ary choice tree model as a model of best-worst choice	**Cole**: Examining working memory during sentence construction with an ACT-R model of grammatical encoding
5:00 PM		Coach to CogSci Hotel		

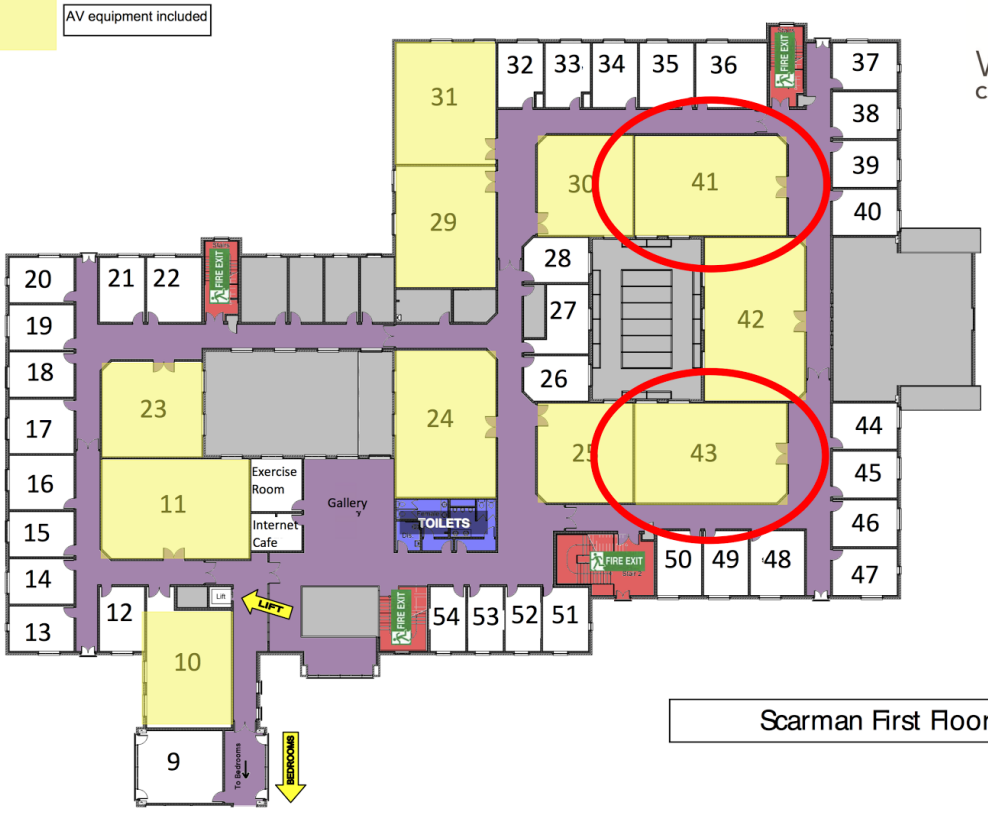
AV equipment included



Entrance

Scarman Ground Floor

AV equipment included



Scarman First Floor

The Slate is across the street from Scarman

Welcome Address

Dear Colleague:

We are happy to welcome you to MathPsych/ICCM 2017, which combines the 50th Annual Meeting of the Society for Mathematical Psychology, the European Mathematical Psychology Group meeting, and the 15th Meeting of the International Conference on Cognitive Modelling. Hosted by the University of Warwick, this year's conference runs from July 22 to 25, and will feature keynote addresses from Peter Dayan, Joseph Houpt (2016 winner of the William K. Estes Early Career Award), and Randy Gallistel. There are also four invited symposia with a total of 25 talks, 142 contributed talks, and more than 70 posters. On the tutorial and workshop day, there are five tutorials, including a professional development symposium hosted by the Women of Mathematical Psychology. This combined conference has attracted more than 270 participants.

The dates, times and room assignments for each talk or poster are given in the margins. Dates such as '23/07' referring to July 23rd, 'Tiered' refers to the Tiered Lecture Theatre (Scarman) which will host the ICCM track. The poster session is from 6-8pm on July 23rd, and posters are given the start time of 6pm on 23/07.

We would like to acknowledge the Society for Mathematical Psychology (SMP), Behavioural Sciences at the University of Warwick, the Artificial Intelligence Journal, and the US Army Research Laboratory and Army Research Office, whose generous support kept the conference fees low and allowed us to fund a large number of student awards. We also would like to acknowledge the people who brought these conferences all together for the first time (Andrew Heathcote, Amy Criss, Frank Ritter, David Reitter, and Matthias Gondan), the hard work of the officers of the SMP (Brent Miller, Leslie Blaha, Richard Golden, and Scott Brown), Jelmer Borst for creating the poster, University of Warwick staff for making the conference tax exempt (Steve McGaldrigan and Jonathan Pearce), and the help of Warwick PhD students on many key aspects of the conference (Alexandra Surdina, Jake Spicer, Mengran Wang, and Jianqiao Zhu).

Best,
Adam Sanborn, Gordon Brown, and James Adelman (MathPsych co-chairs)
Marieke Van Vugt, Adrian Banks, William Kennedy (ICCM co-chairs)

Contents

Abstracts

Some things that glitter are gold: A Shiny app for an Instance-Based Learning model

23/07 09:00
The Slate

Cleotilde Gonzalez, Jeffrey Stephen Chrabaszcz

Carnegie Mellon University, United States of America

Departing from the fact that models are only a representation of reality and not reality itself, all models are wrong. Therefore, building models that are useful and finding ways to effectively communicate their emerging insights are perhaps the most important goals for cognitive modelers. Unfortunately, we are terrible at getting a scientific message across to those less familiar with our models, and we often fall trap of technical complexity. The need for increased transparency, awareness and access to the insights that cognitive models can provide, has motivated the development of tools to give hands-on experiences with cognitive models. In this talk I will present our most recent attempt to make an IBL model useful to researchers and students of behavioral science. Shiny-IBL uses the R package Shiny for generating a web application written primarily in the R language. Shiny-IBL offers a complementary way to communicate the complexity of dynamics emerging from the simple IBL model of binary choice. The main insight from Shiny-IBL is that cognitive modelers should go beyond the explanation of concepts that often need technical expertise and skills, and provide hands-on experiences to demonstrate and communicate the complex insights from their models without the need of additional skills. These interactive tools could also be research tools in their own right. Researchers could use Shiny-IBL to discover a set of inputs that may produce model outputs that may be surprising aspects of human behavior, and be able to understand the reasons behind it.

23/07 09:00
Tiered
Scarman

A computational investigation of sources of variability in sentence comprehension difficulty in aphasia

Paul Mätzig[1], Shravan Vasishth[1], Felix Engelmann[2] and David Caplan[3]
[1] University of Potsdam, Germany, [2] The University of Manchester, [3] Massachusetts General Hospital

We present a computational evaluation of three hypotheses about sources of deficit in sentence comprehension in aphasia: slowed processing, intermittent deficiency, and resource reduction. The ACT-R based Lewis and Vasishth (2005) model is used to implement these three proposals. Slowed processing is implemented as slowed default production-rule firing time; intermittent deficiency as increased random noise in activation of chunks in memory; and resource reduction as reduced goal activation. As data, we considered subject vs. object relatives whose matrix clause contained either an NP or a reflexive, presented in a self-paced listening modality to 56 individuals with aphasia (IWA) and 46 matched controls. The participants heard the sentences and carried out a picture verification task to decide on an interpretation of the sentence. These response accuracies are used to identify the best parameters (for each participant) that correspond to the three hypotheses mentioned above. We show that controls have more tightly clustered (less variable) parameter values than IWA; specifically, compared to controls, among IWA there are more individuals with low goal activations, high noise, and slow default action times. This suggests that (i) individual patients show differential amounts of deficit along the three dimensions of slowed processing, intermittent deficient, and resource reduction, (ii) overall, there is evidence for all three sources of deficit playing a role, and (iii) IWA have a more variable range of parameter values than controls. In sum, this study contributes a proof of concept of a quantitative implementation of, and evidence for, these three accounts of comprehension deficits in aphasia.

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Scarman

Modeling Decision Processes on a Continuous Scale

Roger Ratcliff, Gail McKoon
Ohio State University, United States of America

I present a model for perceptual decision making for stimuli and responses in continuous space on lines, circles, and planes. The experiments use a range of stimulus types, including perceptual, symbolic, dynamic, and static. Participants were asked to make eye movements, mouse movements, or finger movements to, for example, the brightest part of a display or the color on a wheel surrounding a central stimulus that matches the central stimulus. The models are diffusion processes on lines and planes. In the models, evidence from a stimulus drives the noisy decision process which accumulates evidence over time to a criterion at which point a response is initiated. Noise is represented as a continuous Gaussian process or Gaussian random field. The model produces predictions for the full distributions of response times and choice probabilities and fits to data for choice probability, RT distributions, and choice proportion and RT across the stimulus space are presented.

You can't make a silk purse of a sow's ear: On the relative merit of empirical priors in reinforcement learning models

23/07 09:00
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Scarman

Mikhail Spektor[1] and David Kellen[2]

[1] University of Basel, Switzerland, [2] Syracuse University, USA

Formal modeling approaches to cognition provide a principled characterization of observed responses in terms of a set of postulated processes, specifically in terms of parameters that modulate the latter. These model-based characterizations are useful to the extent that there is a clear, one-to-one relationship between parameters and model predictions (identifiability) and that parameters can be recovered from data using a typical experimental design (recoverability). These properties are often insufficiently met for reinforcement learning models, a model class that formalizes learning and decision-making processes in repeated-choice tasks. One suggestion to improve parameter identifiability and recoverability involves the use of so-called empirical priors which constrain parameters according to a previously-observed distribution of values. We assessed the efficacy of the use of empirical priors for reinforcement learning models using a combination of real and artificial data. Our results show that the empirical-prior method did not improve parameter recovery over conventional maximum likelihood estimation. In all cases, recovery was poor, becoming worse with increasing model complexity. Furthermore, neither method could reliably recover the population distributions parameters stem from. We explored whether changes in the task design improved recoverability and identifiability. Our simulations show that offering participants more options to choose from improves both recoverability and identifiability considerably, but the practical difficulties associated to such changes remain to be ascertained. We conclude that instead of focusing on mathematical techniques to alleviate issues of cognitive modeling, researchers should invest their efforts in assessing and improving the information content of the experimental designs used.

Modeling memory biases in decisions from experience

23/07 09:20
The Slate

Elliot Andrew Ludvig

University of Warwick, United Kingdom

When people make decisions based on past experience, they must rely on their memories. These memories, however, are typically not veridical representations of past outcomes. One memory bias that is consistently observed in risky decisions from experience is the overweighting of extreme outcomes. People tend to better remember both the best and worst outcomes in a context. As result, people are more risk seeking for gains and risk averse for losses when those gambles potentially yield either the best and worst outcomes in a decision context.

In this talk, I will discuss a computational model of how memory influences choice in decisions from experience. The model is rooted reinforcement learning and is derived from a related model of classical conditioning in animals. The key idea is that people learn both directly from real experience as it happens, but also from replayed

experiences sampled from memories of past outcomes. This sampling process is biased, such that more recent, more extreme, and more surprising outcomes are overrepresented. I adduce some testable predictions from the model about how the sequence and relative value of outcomes in decisions from experience should affect choice.

23/07 09:20
Tiered
Scarman

Ambiguity Resolution in a Cognitive Model of Language Comprehension

Peter Lindes, John Laird
University of Michigan, United States of America

The Lucia comprehension system attempts to model human comprehension by using the Soar cognitive architecture, Embodied Construction Grammar (ECG), and an incremental, word-by-word approach to grounded processing. Traditional approaches use techniques such as parallel paths and global optimization to resolve ambiguities. Here we describe how Lucia deals with lexical, grammatical, structural, and semantic ambiguities by using knowledge from the surrounding linguistic and environmental context. It uses a local repair mechanism to maintain a single path, and shows a garden path effect when local repair breaks down. Data on adding new linguistic knowledge shows that the ECG grammar grows faster than the knowledge for handling context, and that low-level grammar items grow faster than more general ones.

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Foundations of response time measurement

Matthias Gondan[1] and Steven P. Blurton[2]
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Response times (RTs) inform about the time participants need to detect a stimulus, decide something, or find the correct solution to a problem. RT is, therefore, one of the most important outcome variables in psychology. In cognitive psychology, mean RTs and RT distributions are typically estimated on the basis of the correct responses, after any problematic behavior has been removed from the data (e.g., contaminants such as incorrect responses, omitted responses, outliers). The choice of the criteria for outliers is a matter of ongoing debate, but there seems to be consensus that incorrect responses have to be excluded from the analysis of RT data. In this presentation we challenge this widespread practice. Our basic argument is that any response at time t informs about the time to find the correct solution. This is obvious for correct responses, but in incorrect responses, it indicates that the participant was unaware of the correct response at time t. Disregarding this information yields a biased and incomplete picture of performance. Based on canonical models for choice RT we investigate techniques for imputing correct RTs in incorrect responses and demonstrate how the use of the additional information substantially improves

reliability as well as validity of RT performance estimates. The new methodology enables flexible novel experimental paradigms that do not require ceiling accuracy and allow for effective manipulation of time pressure. We discuss implications for RT research, speed-accuracy trade-offs, and physiological measures.

A simulation study of the strength of evidence in the recommendation of medications based on two trials with statistically significant results

23/07 09:20
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Scarman

Don van Ravenzwaaij[1] and John Ioannidis[2]

[1] University of Groningen, Netherlands, The, [2] Stanford University, USA

A typical rule that has been used for the endorsement of new medications by the Food and Drug Administration is to have two trials, each convincing on its own, demonstrating effectiveness. 'Convincing' may be subjectively interpreted, but the use of p-values and the focus on statistical significance (in particular with p ¡ .05 being coined significant) is pervasive in clinical research. Therefore, in this paper, we calculate with simulations what it means to have exactly two trials, each with p ¡ .05, in terms of the actual strength of evidence quantified by Bayes factors. Our results show that different cases where two trials have a p-value below .05 have wildly differing Bayes factors. Bayes factors of at least 20 in favor of the alternative hypothesis are not necessarily achieved and they fail to be reached in a large proportion of cases, in particular when the true effect size is small (0.2 standard deviations) or zero. In a non-trivial number of cases, evidence actually points to the null hypothesis, in particular when the true effect size is zero, when the number of trials is large, and when the number of participants in both groups is low. We recommend use of Bayes factors as a routine tool to assess endorsement of new medications, because Bayes factors consistently quantify strength of evidence. Use of p-values may lead to paradoxical and spurious decision-making regarding the use of new medications.

Learning from Experiences with Missing Feedback

23/07 09:40
The Slate

Jerker Denrell, Adam Sanborn, Jake Spicer

University of Warwick, United Kingdom

In many real-life settings feedback is only available for cases decision makers accept. How do people learn from such selective feedback? Elwin et al. (2007) provided evidence that people rely on a type of imputation called constructivist coding, i.e., people code rejected cases, for which no feedback is available, as failures. We analyze formally the impact of constructivist coding on the performance of exemplar learning algorithms. Our analysis shows that constructivist coding is an adaptive strategy: it maximizes the total reward. In two experiments we test whether participants impute missing values through constructivist coding, or use a statistical model of the task to correct for selection bias. We find that about half of participants use an exemplar

model; a large majority of these participants use constructivist coding, some of whom internally generate values that are very close to optimal. The other half of participants correct for selective feedback with a sensible task-specific strategy, the majority of whom correct for bias using a Bayesian model of the task. Overall, our findings show that people seem to deal with missing feedback in an adaptive and relatively sophisticated manner.

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Scarman

Feature overwriting as a finite mixture process: Evidence from comprehension data

Shravan Vasishth, Lena Jaeger, Bruno Nicenboim

Potsdam, Germany

The ungrammatical sentence "The key to the cabinets are on the table" is known to lead to an illusion of grammaticality. As discussed in the meta-analysis by Jaeger et al., 2017, faster reading times are observed at the verb are in the agreement-attraction sentence above compared to the equally ungrammatical sentence "The key to the cabinet are on the table". One explanation for this facilitation effect is the feature percolation account: the plural feature on cabinets percolates up to the head noun key, leading to the illusion. An alternative account is in terms of cue-based retrieval (Lewis & Vasishth, 2005), which assumes that the non-subject noun cabinets is misretrieved due to a partial feature-match when a dependency completion process at the auxiliary initiates a memory access for a subject with plural marking. We present evidence for yet another explanation for the observed facilitation. Because the second sentence has two nouns with identical number, it is possible that these are, in some proportion of trials, more difficult to keep distinct, leading to slower reading times at the verb in the first sentence above; this is the feature overwriting account of Nairne, 1990. We show that the feature overwriting proposal can be implemented as a finite mixture process. We reanalysed ten published data-sets, fitting hierarchical Bayesian mixture models to these data assuming a two-mixture distribution. We show that in nine out of the ten studies, a mixture distribution corresponding to feature overwriting furnishes a superior fit over both the feature percolation and the cue-based retrieval accounts.

Hierarchical Hidden Markov Models for Response Time Data

23/07 09:40
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Scarman

Zhifei Yan, Peter Craigmile, Mario Peruggia, Trisha Van Zandt
The Ohio State University, United States of America

Psychological data, particularly those measurements obtained sequentially in experiments designed to test theories and models of human cognition, are often treated as independent and identically distributed samples from a single distribution that describes the random behavior of the cognitive process of interest. This assumption is made for mathematical and analytic convenience; it is widely appreciated that such data are in fact mixtures from two or more processes, a subset of which are associated with the cognitive process of interest. There is a long history of trying to determine the components of psychological data mixtures and estimate the relative contributions of each (see, e.g., Luce, 1986 for a review). Our own work (Kim et al., 2017) has demonstrated the importance of including components to describe fast (subcognitive) and slow (supracognitive) processes that contribute to the measurements derived from the cognitive process of interest. In this project, we build on classic studiesthat attempt to distinguish the separate components of a psychological mixture process (Falmagne, 1965, 1968; Ollman, 1966; Yellott, 1971). Our modeling framework for response time data makes use ofa hierarchical hidden Markov structure. The hidden states of the model are intended to capture the three putative processes (subcognitive, cognitive, and supracognitive) and to describe possibly varying levels of attention within a process. Appropriate parameter specifications allow the processes to evolve over time. The fit of the model is demonstrated on experimental data.

Identifying Probability Modeling Flaws using Generalized Information Matrix Tests

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Richard Mark Golden[1], Steven S. Henley[2,3,6], Halbert White[4] and T. Michael Kashner[3,5,6]

[1] School of Behavioral and Brain Sciences University of Texas at Dallas, [2] Martingale Research Corporation, [3] Loma Linda University School of Medicine, [4] Economics Department University of California at San Diego, [5] Office of Academic Affiliations, [6] Center for Advanced Statistics in Education VA Loma Linda Healthcare System

This talk reviews the unified Generalized Information Matrix Test (GIMT) framework (Golden, Henley, White, and Kashner, 2016, Econometrics) for the development of a wide range of specification analysis methods for determining if a given probability model can adequately represent its statistical environment. The GIMT framework is based upon the classical Information Matrix Equality which states that the inverse Hessian covariance matrix estimator A and the inverse Outer-Product Gradient covariance matrix estimator B are distinct but asymptotically equivalent formulas for estimating the covariance matrix of the maximum likelihood estimates when the probability model is correct. A test of model misspecification can then be derived by testing the null hypothesis that some function f of A, f(A), is equal to

f(B). After introducing key ideas, the distinction between predictive model fit and correct model specification is discussed. Next, the general definitions and assumptions of the GIMT framework are presented followed by the core GIMT theorem. The core GIMT theorem allows one to construct novel statistical tests for a wide range of smooth finite-dimensional probability models. We illustrate the methodology of constructing novel specification tests for a particular probability model and then evaluate their performance using a series of simulation studies. At the end of the talk, we summarize the key ideas for developing and evaluating generalized information matrix tests and provide practical guidelines for implementing these ideas.

23/07 10:00
The Slate

The Wavy Recency Effect of Rare Events and Learning in Different Experimental Settings

Ori Plonsky[1] and Ido Erev[1,2]

[1] Technion - Israel Institute of Technology, Israel, [2] Warwick Business School, Warwick University, UK.

Analyses of human learning reveal a discrepancy between the long- and the short-term effects of outcomes on subsequent choice. The long-term effect is simple: favorable outcomes increase the choice rate of an alternative whereas unfavorable outcomes decrease it. The short-term effects are more complex. Favorable outcomes can decrease the choice rate of the best option. This pattern violates the positive recency assumption that underlies the popular models of learning. The current research tries to clarify the implications of these results. Analysis of wide sets of learning experiments shows that rare positive outcomes have a wavy recency effect. The probability of risky choice after a successful outcome from risk-taking at trial t is initially (at t + 1) relatively high, falls to a minimum at t + 2, then increases for about 12 trials, and then decreases again. Rare negative outcomes trigger a wavy reaction when the feedback is complete, but not under partial feedback. The difference between the effects of rare positive and rare negative outcomes and between full and partial feedback settings can be described as a reflection of an interaction of an effort to discover patterns with two other features of human learning: surprise-triggers-change and the hot stove effect. A similarity-based descriptive model is shown to capture well all these interacting phenomena. In addition, the model outperforms the leading models in capturing the outcomes of data used in the 2010 Technion Prediction Tournament.

Implicit Memory Processing in the Formation of a Shared Communication System

23/07 10:00
Tiered
Scarman

Junya Morita[1], Takeshi Konno[2], Jiro Okuda[3], Kazuyuki Samejima[4], Guanhong Li[5], Masayuki Fujiwara[5] and Takashi Hashimoto[6]

[1] Shizuoka University, Japan, [2] Kanazawa Institute of Technology, [3] Kyoto Sangyo University, [4] Tamagawa University Brain Science Institute, [5] Hokuriku Advanced Science and Technology Graduate School, [6] School of Knowledge Science, Japan Advanced Institute of Science and Technology

This paper presents a simulation study focusing on implicit memory in the formation of a new communication system. In the models presented here, two agents aim to achieve their common goal by exchanging messages composed of two figures, whose meanings are not defined in advance. The effect of implicit memory has been studied with two different symbolic processes, implemented in ACT-R. Our results indicate that the difference caused by symbolic processes reduces when implicit memory is incorporated into the model. We have also found the effect of implicit memory on the creation of an isomorphic communication system, shared among agents. These findings suggest that implicit memory has some roles in the formation of a human communication system.

A motor preparation model account of simple one-choice reaction times

23/07 10:00
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Scarman

Leslie Blaha[1], Christopher Fisher[2] and Lisa Guo[3]

[1] Pacific Northwest National Laboratory, United States of America, [2] Air Force Research Laboratory, United States of America, [3] University of California, Irvine, United States of America

We developed and explored the foundations of a model for continuous (and eventually real-time) information processing. Continuous information processing pertains to considering the dynamics of a decision that includes both the post-stimulus information accumulation and response phases as well as the inter-stimulus interval waiting and anticipation phase. This is in contrast to considering information processing as only a discrete-time even that starts with a stimulus and terminates with a response. Our goal is to model the ways both phases contribute to observed patterns in response times. We investigate how some dynamics of continuous information processing underlying simple reaction times are captured by a trace conditioning model. We fit a version of the trace conditioning model (Machado, 1997; Los, 2001) to human reaction time data from the psychomotor vigilance test (PVT). The PVT requires participants to make a simple button push response as soon as a counter appears on the screen. The trace conditioning model of anticipation can capture foreperiod effects and sequential effects observed in PVT data. These effects are difficult for standard accumulator models of response time to capture. We consider how the trace conditioning approach compares to other recent response time model accounts for PVT data (e.g., Ratcliff & Van Dongen, 2011; Walsh, Gunzelmann,

& van Dongen 2014). We also explore how we might integrate appropriate mechanisms from these two modeling approaches to create a model capturing all phases of continuous information processing.

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Robust Adaptive Design Optimization

Jay Myung, Hairong Gu, Mark Pitt
Ohio State University, United States of America

Accurate and efficient measurement of observations is critical for scientific inquiry. To ensure measurement episodes are also optimal, and thereby maximize inference, there has been a growing interest by researchers in the design of adaptive experiments that lead to rapid accumulation of information about the phenomenon under study with the fewest possible measurements. Our lab has developed one such Bayesian method, dubbed adaptive design optimization (ADO), and has applied it in multiple fields in the behavioral sciences. ADO currently operates under the simplifying assumption that one of the models being tested is the true, data-generating model. This assumption is most certainly violated in practice because all models are imperfect and approximate representations of the underlying system of interest. As such, ADO is not robust. We introduce a semi-parametric Bayesian method that extends ADO to make it robust to model misspecification. Specifically, two statistical tools, Bayesian penalized-splines and Bayesian variable selection, are combined with ADO. Results from preliminary simulations as well as empirical validation of the method will be discussed.

23/07 10:40
The Slate

Modeling adaptive exploration in decisions from experience: A sequential sampling approach

Doug Markant[1], Timothy Pleskac[1], Adele Diederich[2], Thorsten Pachur[1] and Ralph Hertwig[1]

[1] Max Planck Institute for Human Development, Germany, [2] Department of Psychology, Jacobs University Bremen

In decisions from experience, people choose between uncertain prospects based on samples of experience. Past modeling efforts in this area have treated the sampling and choice phases of the task as two independent processes. We review empirical evidence showing that this assumption is often unjustified. Instead, we find that sampling and choice behavior in this task can be described as a sequential sampling process where decision makers sequentially accumulate outcome information from each option to form a preference and make a decision once preference reaches a threshold. Using several existing datasets, we show that this model Choosing from Accumulated Samples of Experience (CHASE) provides a good account of sampling behavior and reveals how different exploratory behaviors impact choice. We also find support for new predictions derived from the model including phenomena like asymmetrical sampling between desirable and undesirable decks. In sum, CHASE

offers a process-level explanation for both sample size and choice across a wide range of conditions when people make decisions from experience. More broadly, the model provides a mechanistic understanding of how interactions between the choice environment and properties of the decision maker give rise to decisions from experience.

How does rumination impact cognition? A first mechanistic model.

23/07 10:40
Tiered
Scarman

Marieke K van Vugt, Maarten van der Velde
University of Groningen, Netherlands, The

Rumination is a process of uncontrolled, narrowly-foused negative thinking that is often self-referential, and that is a hallmark of depression. Despite its importance, little is known about its cognitive mechanisms. Rumination can be thought of as a specific, constrained form of mind-wandering. Here, we introduce a cognitive model of rumination that we developed on the basis of our existing model of mind-wandering. The rumination model implements the hypothesis that rumination is caused by maladaptive habits of thought. These habits of thought are modelled by adjusting the number of memory chunks and their associative structure, which changes the sequence of memories that are retrieved during mind-wandering, such that during rumination the same set of negative memories is retrieved repeatedly. The implementation of habits of thought was guided by empirical data from an experience sampling study in healthy and depressed participants. On the basis of this empirically-dervied memory structure, our model naturally predicts the declines in cognitive task performance that are typically observed in depressed patients. This study shows how we can use cognitive models to better understand the cognitive mechanisms underlying rumination and depression.

Neural Evidence of Insertion and Subtraction of Information Processing Stages

23/07 10:40
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Scarman

Qiong Zhang, Matthew Walsh, John R Anderson
Carnegie Mellon University, United States of America

In this EEG study, we investigated compositions of information processing stages underlying different problem solving paths. In each trial, participants viewed two numbers or a number and a letter. Letters corresponded to previously memorized digits. Participants were asked to type the values of the two stimuli, or to type the product of the values. In this way, all trials shared the same starting (encoding) and ending (motor response) points, but passed through different branching structures based on whether a variable value, a multiplication fact, or both needed to be retrieved. This created four types of problems in total (Null, Memory, Math, Both). We analyzed the behavioral and EEG data using a combination of multivariate pattern analysis with hidden semi-Markov models. Using model parameters obtained

from the three simpler conditions (Null, Memory, and Math), we could additively construct the sequence of stages observed in the most complex condition (Both). These data provide evidence of pure insertion, and support Sternberg's additive factors logic.

The Power Law of Visual Working Memory Characterizes Attention Engagement

23/07 10:40
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Scarman

Philip L Smith[1], Simon D Lilburn[1], Elaine A Corbett[1] and Soeren Kyllingsbaek[2]
[1] The University of Melbourne, Australia, [2] The University of Copenhagen, Denmark

The quality or precision of stimulus representations in visual working memory can be characterized by a power law, which states that precision decreases as a power of the number of items in memory, with an exponent whose magnitude typically varies in the range 0.5 to 0.75. We show that the magnitude of the exponent is an index of the attentional demands of memory formation. We report five visual working memory experiments with tasks that varied in their attentional demands and show that the magnitude of the exponent increases systematically with the attentional demands of the task. Recall accuracy in the experiments was well described by a model that views visual working memory as a population of noisy neurons that can be allocated flexibly under attentional control. The magnitude of the exponent indexes the degree to which attention allocates neural resources to items in memory unequally rather than equally.

The impact of presentation/evaluation format on preference formation and risk biases

23/07 11:00
The Slate

Marius Usher[1], Michael Brusovansky[1], Yonatan Vanunu[1] and Thorsten Pachur[2]
[1] Tel-Aviv University, Israel, [2] Max-Plank Institute, Berlin

Value integration is a general mechanism assumed to mediate the preferences formation of alternatives based on multiple rewards, as in experience-based decisions or in attitude-formation. Two possible versions of this mechanism have rarely been contrasted: accumulators vs. summary statistics. Based on computational considerations we predict that the mechanism deployed depends on the presentation/evaluation format. Under grouped presentation/evaluation conditions (samples from a group of alternatives presented and evaluated together) we expect that participants deploy an accumulator mechanism - a separate accumulator sums the rewards of each alternative. Under one-by-one presentation/evaluation conditions (each alternative presented/evaluated separately), we expect that preferences are driven by the statistical summaries of the alternatives (Average, SD). In two experiments carried out to test these predictions, participants were asked to rate the same set of alternatives (sequences of slot-machines' rewards), both in a grouped and a one-by-one format. In Exp-1, we orthogonally varied the averages of the alternatives and the number of samples. In line with our predictions, we found that in the

one-by-one condition, ratings were affected only by the average (summary statistics mechanism), while in the grouped condition, ratings also increased with the number of samples (accumulator mechanism). In Exp-2, we examined risk attitudes by orthogonally varying the average and variance of the alternatives. We found that in the one-by-one condition preferences are best accounted by the summary statistics (risk-return) model, while in the grouped condition by a selective-accumulator model, which exhibits risk aversion at low values and risk-seeking at high values.

A computational cognitive-affective model of decision-making

23/07 11:00
Tiered
Scarman

Christopher Lee Dancy, David Schwartz

Bucknell University, United States of America

How do affective processes interact with cognitive processes to modulate our behavior? Understanding the processes that influence the interactions between affective stimuli and human decision-making behavior is important for predicting typical behavior under a variety of circumstances, from purchasing behavior to deciding when to enact certain rules of engagement in battle scenarios. Though some computational process models have been proposed in the past, they typically focus on higher-level phenomena and are less focused on the particular architectural mechanisms related to the behavior explored. This, in turn, can make it very difficult to combine the proposed model with existing related work (i.e., the models can't be tractably combined). We used a modified version of the Iowa Gambling Task to explore the effects of subliminal affective (visual) stimuli on decision-making behavior. We developed a model that runs within the ACT-R architecture that completes the same task completed by participants. In addition to the affective and cognitive memory components particularly important to the discussion, the model also uses perceptual and motor components within the architecture to complete the task. The architecture has representations of primitive affect that interact with cognitive memory components mainly through an affective-associations module (meant to capture behavior typically ascribed to several amygdalar substructures). The model and affective architectural mechanisms provide a process-oriented explanation for the ways affect may interact with higher-level cognition to mediate human behavior during daily-life.

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Implementation of Adaptive Design Optimization in functional MRI experiments

Giwon Bahg, Per Sederberg, Jay Myung, Mark Pitt, Zhong-Lin Lu, Brandon Turner

The Ohio State University, United States of America

In the era of model-based cognitive neuroscience, the efficiency of experimental design is one of the most important methodological issues to maximize information obtained within a limited number of trials. Its importance becomes even greater considering high cost of data collection in neuroimaging studies. One of the possible solutions is Adaptive Design Optimization (ADO; Cavagnaro, Myung, & Pitt, 2010), which is a design optimization technique based on mutual information and Bayesian inference, and has already been applied to behavioral experiments. To validate its practicability in neuroimaging experiments, we here present a proof-of-concept study of the implementation of ADO for model-based functional MRI experiments, focusing on parameter estimation. We will first discuss two possible ways to apply ADO in neuroimaging studies: (1) relying on behavioral responses with an assumption that they embody core features of target neural activity, and (2) directly including neural signals in the computation procedures of ADO using Joint Modeling Framework (Turner et al., 2013) and real-time fMRI. A simulation study based on a contrast discrimination task will be demonstrated subsequently as an example of the ADO implementation, with a goal of estimating parameters in the Naka-Rushton equation and the Thurstonian decision model. The efficiency of the ADO-based approach is compared to that of a purely random experimental design, and the implications of model-based fMRI experiments are discussed.

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Visual working memory for dynamic human movement: A normative computational account

Rachel Ann Lerch, Jinghan Wan, Chris R. Sims

Drexel University, United States of America

Existing research in visual working memory (VWM) largely focuses on memory for simple and static stimuli. In contrast, we explored VWM for complex human movement. Using motion capture footage of expert and novice martial artists executing the same kicks and strikes, along with techniques for morphing, we created a continuous stimulus set of video clips ranging from one magnitude of expertise to the other (e.g. morph mixture of 80% expert, 20% novice). The following URL illustrates examples from the stimuli set http://www.pages.drexel.edu/ crs346/MathPsych17.html. These stimuli were used to implement a standard change detection paradigm; subjects were shown one clip, and after a delay shown a clip that was either identical, or perturbed (shifted in either expertise direction). Across ten sessions, observers demonstrated significant increases in VWM performance.We explored how visual learning and VWM are intrinsically linked by applying a computational framework based on rate-distortion theory, a branch of information theory that provides optimal bounds on the accuracy of information transmission subject to a fixed capacity.

Unlike alternative models of VWM, this framework provides a normative basis for understanding performance changes. Specifically, this framework states that an efficient communication channel must possess three properties: knowledge of relevant statistical regularities, an adequate channel capacity to transmit that information, and a cost function defining the cost of memory errors. The results of our analyses indicate that channel capacity estimates increase across sessions with visual learning, and suggest improved statistical sensitivity for what types of information to attend to and prioritize in memory.

Rapid experiential decisions as a window to paradoxical multiattribute and risky choice patterns

23/07 11:20
The Slate

Konstantinos Tsetsos

University Medical Center Hamburg, Germany

Real-life decisions entail integrating information across different attributes. When making such multiattribute decisions humans represent the value of alternatives in a context-sensitive fashion. That is, contrary to the prescriptions of rational choice theory, the subjective value assigned to an alternative is influenced by the attribute values of other competing alternatives. Computational insights about the nature of this contextual-sensitivity are scarce, mainly because typical experimental approaches involving choices between consumer goods or gambles offer no precise control over the information flow preceding each decision. To circumvent this problem, and inspired by research in perception and visual psychophysics, I will present a paradigm that abstracts multiattribute decisions into simpler, rapid experiential decisions. I will show that classical choice paradoxes such as violations of regularity and transitivity can be obtained using this simple task. These effects are explained by a single mechanism based on heightened (selective) attention towards more valuable or salient samples of incoming information. Following this selective integration framework, risk attitudes do not reflect the non-linearities of static value functions but the dynamics of context-sensitive valuation and value accumulation. I will present experimental results that verify this hypothesis by probing risk-attitudes in rapid experiential decisions. I will close by alluding to ways that the selective integration framework can explain aspects of the description-experience gap.

23/07 11:20
Tiered
Scarman

A New Direction for Attachment Modelling: Simulating Q Set Descriptors

Dean David Petters
Birmingham City University, United Kingdom

Attachment modelling is an emerging field at the intersection of research in Attachment Theory and computational modelling of emotion. Existing attachment models vary from very abstract models to simulations of specific experimental protocols, such as the Strange Situation Procedure. This paper argues for the benefits in broadening attachment modelling of infants and young children to also include simulating attachment Q set descriptors. These descriptors provide a broader and more rounded challenge for attachment modelling because they can be observed in naturalistic contexts and are less dependent on the specific details of laboratory settings. A computational model is presented which simulates a selection of attachment Q set descriptors. This is an extension of a model designed to simulate the Strange Situation Procedure. A 'route map' for future developments towards capturing all Q sort descriptors is discussed.

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Scarman

Model-based cognitive neuroscience for the chronometry of simple human decision making

Michael D. Nunez, Ramesh Srinivasan, Joachim Vandekerckhove
University of California, Irvine, United States of America

Our goal is to discover and test theories about the time-course of speeded human decision making using model-based cognitive neuroscience methods with measured neural processes. The chronometry of participants' neural behavior was explored by finding stimulus-onset and motor response event-related potentials (ERPs) as measured by the electroencephalogram (EEG). The chronometry of participants' decision-making cognition was estimated by finding Bayesian posterior distributions of diffusion model parameters, a model-type that explains both accuracy and reaction time behavior. Both neural measures and behavior were used in hierarchical Bayesian model-based cognitive neuroscience approaches to separate reaction times into three components: visual encoding, decision-making, and motor response, resulting in both participant-level and single-trial level estimates of these time periods in milliseconds. The veracity of estimating visual encoding times with evoked EEG responses to visual stimuli (negative potentials over parietal electrodes around 200 milliseconds) will be discussed. The veracity of using motor evoked potentials (activity generated by the motor cortex before response execution) as estimates of motor preparation times will be discussed. Integrated models of both cognition and electrocortical activity are able to predict known and new subjects' accuracies and reaction time distributions out-of-sample. Future applications of using neural data to constrain cognitive models will be discussed.

Hierarchical Bayesian Cognitive Model-based Meta-analysis

23/07 11:20
Space 43
Scarman

Chris Donkin[1], Robert Taylor[2], Daniel J. Navarro[1] and Timothy Pleskac[3]
[1] UNSW Sydney, Australia, [2] Cambridge University, [3] Max Planck Institute, Berlin

We propose a method that uses hierarchical Bayesian techniques to estimate the parameters of cognitive models using multiple sources of data - from individual-trial level data all the way through to population-level estimates of parameters. Aggregating within a literature is difficult, because of the many ways in which data are reported; There are some wonderful people who post entire data sets, but the norm is still to report aggregate-level statistics from (potentially) multiple tasks, with (potentially) multiple dependent variables. We show that sometimes there may be different data-generating models for these different sources of data that are all informing single population-level parameters of cognitive models. We first work through a simulation-based example using signal detection. Then, we apply the technique to real data in the domain of visual working memory, where we attempt to estimate the number of simple color items that can be held in memory. The data come from change-detection and recall tasks, and range from being full individual-trial data sets, to individual-participant parameter estimates, to summary statistics for percentage correct, hit and false alarm rates, and parameter estimates. We attempt to use all of these sources of data to inform our estimates of the population-level parameters of the cognitive models.

Different choice environments affect recency patterns not preferences

23/07 11:40
The Slate

Nathaniel Ashby[1], Nick Chater[2] and Ido Erev[1,2]
[1] Techinon - Israel instititue of Technology, [2] University of Warwick

Many choices rely on two classes of evidence: Evidence collected in previous tasks, and evidence collected in order to inform the current task. Research suggests that these two classes of evidence are integrated and impact behavior differently. Specifically, analyses of the evidence collected in previous decisions (using the clicking paradigm) reveal a robust bias towards underweighting of rare outcomes and a wavy-recency effect, while analyses of the evidence collected prior to the current choice (using the rapid-serial-visual-presentation, RSVP paradigm) suggest an overweighting of high extreme (rare) outcomes and a positive recency effect.

The current work seeks to clarify the relationship between these distinct effects of observed outcomes on preference. It shows that the experimental paradigm itself has a large effect on the recency pattern. The wavy recency effect emerges in the clicking paradigm, and the RSVP paradigm triggers a positive recency effect. In contrast, the impact of the experimental paradigm on aggregate choice rates is eliminated by feedback with underweighting of rare events being observed in both paradigms. Comparison of alternative explanations of these patterns favors the hypothesis that feedback triggers reliance on small samples of "similar" past experiences (implying underweighting of rare events), and the experimental paradigm

determines which previous outcomes are considered to be most similar which affects the recency pattern.

A computational model of focused attention meditation and its transfer to a sustained attention task

23/07 11:40
Tiered
Scarman

Amir Josef Moye[1] and Marieke van Vugt[2]
[1] University of Bern, Switzerland, [2] University of Groningen

Although meditation and mindfulness practices are widely discussed and studied more and more in the scientific literature, there is little theory about the cognitive mechanisms that comprise it. Here we begin to develop such a theory by creating a computational cognitive model of a particular type of meditation: focused attention mediation. This model was created within Prims, a cognitive architecture similar to and based on ACT-R, which enables us to make predictions about the cognitive tasks that meditation experience may affect. We implemented a model based on an extensive literature review of how the meditation experience unfolds over time. We then subjected the Prims model to a session of the Sustained Reaction to Response Task, a task typically used to study sustained attention, a faculty that may be trained with meditation practice. Analyses revealed that the model was significantly more sensitive to detecting targets and non-targets after the meditation practice than before. These results agree with empirical findings of a longitudinal study conducted in 2010. These results suggest that our approach to modeling meditation and its effects of cognition is feasible.

A neurally plausible model for generating probability estimations from a quantum decision making model

23/07 11:40
Space 41
Scarman

Andrei Teodorescu[1] and Jerome Busemeyer[2]
[1] University of Haifa, Israel, [2] Indiana Univarsity, USA

Mathematical models based on quantum probability theory have been increasingly used to describe human judgment and decision making. One of the main advantages of Quantum models is their ability to naturally capture biases in probability estimation judgments such as the conjunction and disjunction fallacies (Busemeyer et al. 2011) as observed in the Linda problem. For example, in the conjunction fallacy, the probability of the conjunction of events P(A & B) is judged as more likely than one of its constituents e.g. P(A). In a Quantum probability model, the probability of an event is calculated as the squared magnitude of the amplitude. However, the use of the squared amplitude has been often ambiguous as it was used both to calculate the probability of an event (e.g. P(yes) to the question is Linda a feminist?) and also to calculate the judgment about the probability of the event (e.g. the observed judgment in response to the question: what is the probability that Linda is a feminist). While this duality has been successful in capturing human behavior, it remains unspecified how and why should these two dependent variables be the

same. In this talk I will present a theory of probability judgments that that offers a neutrally plausible process for generation of probability estimations from a quantum probabilistic representation of event probabilities. The theory conforms with, and resolves the event-probability vs. probability-estimation duality by assuming a parallel distributed architecture. Implications of the theory, and empirically testable predictions form a corresponding model will be discussed.

A hierarchical Bayesian approach to state trace analysis with application to implicit visual memory

23/07 11:40
Space 43
Scarman

Patrick S. Sadil, Kevin Potter, David Huber, Rosemary A. Cowell

University of Massachusetts, United States of America

We used continuous flash suppression (CFS) to induce learning about visual objects without awareness. After learning under CFS, participants were tested on part-whole cued recall (naming the object from a part) and part-matching (intact-rearranged 2AFC recognition for pairs of parts). Performance dissociated on the two tests, suggesting that CFS creates implicit visual memory of object form in the absence of explicit memory for semantic identity. This conclusion was reached using state trace analyses. In state trace, two dependent measures (e.g., cued recall versus recognition) are plotted on the X and Y axes, with different plotted points for the means of different conditions. The critical question is whether a monotonic function can pass through all points: if not, more than one latent variable likely underlies the dependent measures. In evaluating the adequacy of a monotonic function, the dependent measures are typically assumed to be independent (variance of the mean along the X axis unrelated to variance along the Y axis). However, for most applications of state trace, this is unlikely to be true: a monotonic function that successfully passes through the means under this independence assumption may fail when allowing for covariance between the dependent measures. In our state trace analysis, we used hierarchical Bayesian modeling in which the dependent measures were assumed to reflect bivariate normal distributions, with items and subjects as random factors. Applying this to our data, we were able to reject a monotonic function both via assuming independence and via the hierarchical Bayesian approach that incorporated covariance.

23/07 13:10
The Slate

Betwixt fast and slow: Integrating model-free and model-based decision-making

Peter Dayan

UCL, United Kingdom

Behavioural and neural evidence reveals a retrospective, model-free or habitual process that caches returns previously garnered from available choices, and a prospective, model-based or goal-directed one that putatively relies on mental simulation of the environment. There is much current interest in understanding how these faster and slower systems are integrated to take advantage of the beneficial computational properties of each. I will discuss a recent study looking theoretically and empirically at the incorporation of model-free values into model-based calculations. This is joint work with Mehdi Keramati, Peter Smittenaar and Ray Dolan.

23/07 14:40
The Slate

Balancing the Evidence on 'Don't Know' and Confidence Judgments

Andrew Heathcote

University of Tasmania, Australia

Balancing the Evidence on 'Don't Know' and Confidence Judgments

Andrew Heathcote[1], Jim Sauer[1], Rod Garton[1], Matthew Gretton[1], Valera Griffin[1], Matthew Palmer[1], Beatrice Bora[2] and Adam Osth[3]

[1]Division of Psychology, University of Tasmania, Australia.

[2]School of Psychology, University of Newcastle.

[3]School of Psychological Sciences, University of Melbourne.

We develop an analytic version of Vicker's 'Balance of Evidence' mechanism for explaining response time (RT), choices and confidence. We apply it to recognition memory data in which participants simultaneously rated their choice and confidence or could make a 'Don't Know' response instead of choosing whether a test item was a target or lure. We also extended the model to account for asymmetric calibration of confidence for target and lure responses. We discuss the broader application of this modeling framework to any uni-dimensional judgment and to series of related responses (e.g., making a choice followed by a confidence rating of that choice).

Building an ACT-R reader for eye-tracking corpus data

23/07 14:40
Tiered
Scarman

Jakub Dotlacil

University of Amsterdam, Netherlands, The

ACT-R has been successfully used in psycholinguistics to model experimental processing data. In this paper, I show how it could be further scaled up to model a much larger set of data, eye-tracking corpus data. It is shown that the resulting model has a good fit to the data in the considered (low-level) processes. Furthermore, it is argued that free parameters of ACT-R could and should be estimated using the well-established methods in other fields, rather than by manually searching through parameter space. The latter option is simply impossible to use once we hit the amount of data considered here. The latter option also makes it hard, if not impossible, to compare parameters across different (ACT-R) models since manual search is subjective and usually not well documented in research papers.

Inferring decision strategy: Explorations in integrating multiple sources of behavioral data

23/07 14:40
Space 41
Scarman

Michael Lee[1], Matthew Walsh[2] and Kevin Gluck[3]

[1] University of California - Irvine, [2] TiER 1 Performance Solutions, [3] Air Force Research Laboratory

Most of the published research on decision strategy inference relies exclusively on the decisions that were made as the evidence base for the inference. A small minority of this literature includes information search, such as the number and sequence of cues revealed, as a form of process data to inform the strategy inference. Here we report our progress in integrating decision and search behavior with another form of process data, concurrent verbal protocols. The presentation will describe a method for combining these sources of evidence using common cause models implemented as Bayesian graphical models. We show how using multiple sources of behavioral evidence allows for more confident inferences about strategy use based on fewer trials. We also examine cases in which decisions, search, and verbal protocols provide conflicting evidence about strategy use, and explore how Bayesian inference resolves these uncertainties.

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Scarman

Human episodic memory retrieval is accompanied by a neural jump back in time

Sarah Folkerts[1], Ueli Rutishauser[2,3] and Marc Howard[4]

[1] Warwick University, United Kingdom, [2] Department of Neurosurgery, Cedars-Sinai Medical Center, [3] Computation and Neural Systems, California Institute of Technology, [4] Psychological and Brain Sciences, Boston University

Cognitive psychologists have long hypothesized that experiences are encoded in a temporal context that changes gradually over time. When an episodic memory is retrieved, the state of context is recovered a jump back in time. We recorded from single units in the MTL of epilepsy patients performing an item recognition task. The population vector changed gradually over minutes during presentation of the list. When a probe from the list was recollected, the population vector reset to the neighborhood of the original presentation of that probe during study: a neural jump back in time. Probes that were not recollected did not cause a jump back in time. These results constitute the first direct evidence that recollection of an episodic memory in humans is associated with recovery of a gradually-changing state of temporal context: a neural jump-back-in-time that parallels the act of remembering

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23/07 15:00
The Slate

The box model - a dynamic stochastic approach for decision making with n alternatives

Keivan Karai, Adele Diederich

Jacobs University Bremen, Germany

Dynamic stochastic models for decision making with multiple choice options become increasingly important for various applications and explanation for context effects (e.g., MDFT, LCA, AA, MLBA). Here we introduce a model that is similar to those models in some aspect but different with respect to others. In this model the continuous time information sampling is driven by a Wiener process with drift in a Euclidean space of dimensions n, where n is the number of alternatives. The covariance matrix of the Wiener process allows us to quantify the dependencies between the accumulation process for different alternatives. The stopping criterion is determined by the order statistic of a sequence of stopping times, each a first passage time associated to acceptance or rejection of one alternative. Our investigation is based on analyzing the relation between these stopping times.

We specifically study a slight variation of this model involving two principal and one fall-back alternative, and discuss various technical issues related to obtaining analytic solutions for the reaction time and the choice probabilities. In contrast to the one-dimensional models, closed analytic solutions seem to be out of reach, but using tools from martingale theory we will provide answer in some special cases.

Data-driven process models and brain-lesion data: how patient-based analyses can inform us about interference and cognitive control

23/07 15:00
Tiered
Scarman

Royce Anders[1], Stephanie Riès[2,3], Leendert Van Maanen[4] and F.-Xavier Alario[1]

[1] Aix Marseille Univ, CNRS, LPC, Marseille, France, [2] Department of Psychology and Helen Wills Neuroscience Institute, University of California, Berkeley, CA, USA, [3] School of Speech, Language, and Hearing Sciences, San Diego State University, San Diego, CA, USA, [4] Department of Psychology, University of Amsterdam, The Netherlands

In this talk, I will discuss recent developments in data-driven accumulation-to-bound process models (e.g. sequential sampling models), and demonstrate how we have advanced findings in our domain through incorporating brain-lesion patient data, in which these lesions were localized to the left pre-frontal cortex through brain-imaging work (fMRI). Particularly, patients with lesions in the left prefrontal cortex (PFC) have been shown to be impaired in lexical selection, especially when interference between semantically-related alternatives is increased. Current theory has considered that task inference is handled by cognitive control, which works have identified in the brain with frontoparietal activity (e.g. Badre, 2008; Koechlin et al., 2003). Recent model-based neuroscience work involving accumulation models with healthy participants, consider such control to be handled by decision threshold modulation (e.g. Domenech & Dreher 2010; Forstmann et. al 2010). Herein by analyzing patients specifically with PFC lesions, and comparing them to healthy speakers on lexical selection, we indeed find deficits in appropriate modulation of the decision threshold as task interference is introduced. The modeling also provides accounts for how such mechanisms may be modulated by other task factors such as repetition and trial lag.

A Thurstonian Investigation into the Relationship Between Probabilistic and Temporal Discounting

23/07 15:00
Space 41
Scarman

Pele Schramm

University of California, Irvine, United States of America

The value of an option for a monetary reward decreases both as the probability of receiving it decreases, as well as the delay before receiving it increases. Temporal and Probabilistic discounting have long been thought to be connected, with discounting curves taking a similar mathematical structure when treating odds against reward as a replacement for delay. A Bayesian Hierarchical approach utilizing the assumptions of the Thurstone model is introduced. The approach allows for the measurement of discounting curves across multiple monetary amounts to be measured simultaneously, fitting smooth nonlinear functions denoting changes in discounting parameters over different monetary amounts and converting monetary value to Thurstonian value. Paired comparisons are assumed to take the form of a Thurstonian Case III model where valuation is assumed to be Gaussian distributed with different levels of variance for different options. Likert-style questions are also utilized for various sampled options, with the response providing additional information on value, and

the deliberation time providing additional information on the level of uncertainty in an options value. The change in discounting parameters for different monetary amounts in temporal and probabilistic domains will be compared both at the individual level and the group level, as well as the changes in the uncertainty in value for different money-delay/probability combinations.

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Scarman

Episodic Memory and Spatial Navigation in the Medial Temporal Lobe

David Huber[1] and Solstad Trygve[2]

[1] University of Massachusetts, Amherst, United States of America, [2] Norwegian University of Science and Technology, Norway

Hippocampal place cells and entorhinal grid cells are abundant, suggesting that the medial temporal lobe (MTL) primarily supports spatial navigation. At the same time, neuropsychological studies find that the MTL supports the formation of episodic memories. We explain this seeming contradiction with a hierarchical memory model in which episodic memories are points in a high dimensional space. Because the X/Y dimensions used to analyze place and grid cells are part of this representation, different levels of the hierarchy give the appearance of place and grid cells when only analyzed in terms of the X/Y plane. We propose that X/Y position information is provided by border cells, which is combined with the true attributes of grid cells (e.g., something other than X/Y) to produce cognitive maps and ultimately multidimensional episodic memories in the hippocampus. Place cell responses are retrieved memory responses that occur when the animal is in a position sufficiently close to the location of a prior experience. Memory consolidation separates memories in the multidimensional space, producing a hexagonal array of place cells. The response of a cell representing a non-spatial attribute common to the entire set of memories is hexagonal in the X/Y plane owing to excitatory feedback from each place cell. Thus, rather building place cells out of grid cells, as proposed by other models, our account builds grid cells out of place cells. Furthermore, our account proposes that place cells are episodic memories and grid cells are non-spatial.

Constraining computational models of decision-making with equal-evidence perceptual tasks

23/07 15:20
The Slate

Ryan Pierce Kirkpatrick, Brandon Turner, Per Sederberg
The Ohio State University, United States of America

The diffusion decision model (DDM) has successfully accounted for a wide range of choice–response-time data for decades. One key assumption of the accumulation dynamics within the DDM is that the evidence accumulated between two alternatives is perfectly anti-correlated. To date, little research has investigated whether this assumption is justified. To test this assumption, we designed a two-alternative random-dot motion task where we manipulated the proportion of dots coherently moving right and left in the same stimulus. Critically, we included trials where an equal proportion of dots coherently moved in both directions with variable levels of total coherence. In these equal-coherence conditions, we observed increasing response times with increasing coherence, a result that proved difficult for models that assume equal trade-off between accumulator growth. Our second analysis involved the computationally simple linear ballistic accumulator model (LBA), which assumes an independent race between alternatives. We found that, while the LBA model could account for the choice–response-time distributions for the equal coherence conditions, it failed to simultaneously account for those in the unequal coherence conditions. Given these results, our third analysis fitted the leaky competing accumulator (LCA) model to our data. We found the LCA model, which allows for a dynamic, interactive accumulation process among the choice alternatives, provided the best account. Taken together, our results suggest that only racing accumulator models with some element of competition are able to successfully account for this particular ensemble of stimuli.

Combining Space and Time in the Mind

23/07 15:20
Tiered
Scarman

John R Anderson
Carnegie Mellon, United States of America

Many cognitive modeling efforts are concerned with when cognitive events occur in time and many cognitive neuroscience efforts are concerned with where things are happening in the brain. We have combined hidden semi-Markov models (HSMM) and multivariate pattern analysis (MVPA) to merge the information from both sources. I will describe how we have used HSMM-MVPA to both discover and test models of cognitive processes.

23/07 15:20
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Scarman

Linking emotion to decision making through model-based facial expression analysis

Nathaniel Haines, Yitong Shen, Woo-Young Ahn
The Ohio State University, United States of America

Emotions play a large role in human decision making, yet measuring emotions in real-time and incorporating them into cognitive modeling remains elusive. Growing evidence suggests that facial expressions (FEs) provide an objective measurement of emotions and FEs might provide useful information about people's underlying states/intentions. While previous studies have investigated general relationships that FEs have with decision making, a formal link between the two remains unknown. Thus, we aimed to identify a cognitive mechanism linking value-based decisions and the FEs expressed during a decision making task.

Volunteers (N=22) underwent two-armed bandit tasks, where one choice in each task was associated with a certain reward and the other with a probabilistic reward, the probability of which had to be learned from experience. The payoffs of both chosen and unchosen options were revealed on every trial (full information). To measure FEs, we used a computer vision tool that detects the temporal dynamics of twenty Action Units as described by the Facial Action Coding System. To determine the cognitive mechanisms linking choice behavior to FEs, we took a joint modeling approach we developed a novel reinforcement learning model which incorporated FEs to estimate free parameters of the model.

Preliminary results suggest that a model assuming that people maximize subjective emotional expectations, which are jointly estimated by FEs and choice outcomes, provides a better explanation for participants' choice behavior than other competing models. This work represents a novel model-based FE analysis, and our results shed light on the mechanistic links between cognition and emotion.

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Scarman

Title: Using neural data and machine learning to distinguish between models of recognition memory

Christoph Thomas Weidemann[1] and Michael J. Kahana[2]
[1] Swansea University, United Kingdom, [2] University of Pennsylvania

A repeated encounter with a person or object frequently elicits feelings of familiarity and recollections of previous interactions. The question of whether these constitute independent signals for recognition has been an issue of contention for decades. We used statistical ("machine learning") classifiers trained on spectral EEG activity before an overt response was made to track the accrual of neural evidence for recognition decisions as a function of time. Performance and output of these classifiers corresponded closely with overt responses (confidence ratings and response times) and, at each time point, appeared to track accumulated evidence with negligible contributions from earlier neural features. Fits of a drift diffusion model to overt responses improved when setting drift rate to be a linear function of trial-by-trial classifier output. These results indicate an ongoing, continuously accruing, memory

strength signal that incorporates any recollective information and forms the basis for recognition memory decisions.

The impact of the strength and duration of early information on perceptual decision-making

23/07 15:40
The Slate

Jennifer Trueblood[1], William Holmes[1] and Andrew Heathcote[2]

[1] Vanderbilt University, United States of America, [2] University of Tasmania, Australia

How do people adapt to and integrate changed information in their decision-making? Through a series of experiments, we explored this question in a perceptual decision-making task where participants made decisions about the color of a flickering grid of pixels. The grid contained two colors in different proportions. Every few frames the pixels were rearranged randomly, but the color portions remained the same. Participants decided on the majority color. On some trials, the color portion was changed part way through the trial (e.g., majority color became the minority color). The experiments manipulated the timing of the color change and the strength of evidence before and after the change.

We used the piecewise Linear Ballistic Accumulator (pLBA) model to examine how the strength and duration of the initial perceptual evidence impacted decision processes. We find that drift rates and the rate delay (time between physical change of information and perceived change) are sensitive to the amount and quality of early information. We discuss how these results could arise from a nonlinear process involving responses from transient and sustained channels that are integrated in visual short term memory. We believe pLBA provides an approximation to this underlying nonlinear process.

Understanding the Dynamics of Decision Boundaries in the Brain

23/07 15:40
Tiered
Scarman

Leendert Van Maanen

University of Amsterdam, Netherlands, The

To gain a better understanding of the cognitive mechanisms underlying choice it is often useful to explicate theories with formal cognitive models. In the domain of perceptual choice, this approach has a relatively long tradition, and has helped in identifying the role of certain brain regions in determining decision boundaries. In particular, based on accumulator models of decision making, it has been shown that individual differences in average BOLD responses in the striatum reflect the difference between decision boundary estimates for speed-stressed and accuracy-stressed conditions (Forstmann et al., 2008), and that trial-to-trial fluctuations in striatal BOLD prior to stimulus onset reflect trial-to-trial fluctuations in the decision boundary (Van Maanen et al., 2011).

In the current work, we extend these results and show that also time-variant changes in the decision boundary (i.e., within a single-trial) are reflected by striatal

BOLD responses, both in terms of individual differences (Van Maanen et al., 2016) and in terms of trial-to-trial variability. These results are in support of models of decision making that propose time-variant decision boundaries (e.g., Cisek et al., 2009, Drugowitsch et al., 2012, Frazier & Yu, 2008).

Modeling individual and developmental differences of strategy use in decision-making tasks: A Bayesian hierarchical approach

23/07 15:40
Space 41
Scarman

Helen Steingroever, Hilde Huizenga
University of Amsterdam, Netherlands, The

Analyses of data from proportional-reasoning, categorization and decision-making tasks revealed large individual and developmental differences in strategy use. For example in decision-making tasks, optimal performance is obtained by using an integrative strategy that focuses on the expected value of the options. However, it is plausible that simpler, sequential strategies are used. Such strategies assume that decision makers start by comparing the options on the most important cue; if the options differ on this cue, a decision is made; otherwise the options are compared on the second most important cue, etc. Here we present a model based on Lee and Wagenmakers (2014; Chapter 18) that detects individual and developmental differences in strategy use. We demonstrate a Bayesian hierarchical implementation of our model using a parameter recovery study and an application to a published dataset. This dataset consists of 231 children and adolescents (age range = 8-17 years) who performed a decision-making task without feedback. We also discuss an extension of the model to tasks with feedback, in which participants may switch between strategies as a reaction to the obtained feedback.

Toward a unified mathematical model of episodic memory

23/07 15:40
Space 43
Scarman

Marc Howard
Boston University, United States of America

Over the last several decades, mathematical psychologists have developed models of recognition and recall that have been largely independent of one another. I discuss recent developments in neurophysiology that suggest a common framework that can account for properties of both classes of tasks. The framework includes a scale-invariant neural timeline that mimics at short time scales multitrace models and at longer time scales global match models of recognition memory. In order to make sense of contiguity effects in recall and recognition tasks, the framework must also incorporate a "jump back in time" mechanism whereby prior states of the timeline are transiently recovered.

Multi-alternative decision making is affected by value-based attentional capture

23/07 16:20
The Slate

Sebastian Gluth, Mikhail Spektor, Jörg Rieskamp
University of Basel, Switzerland

Humans and other species often violate economic choice principles when choosing between more than two alternatives, but the underlying cognitive and neural mechanisms remain elusive. A robust finding is that adding a third option can change the relative preference for the original alternatives, but studies disagree on whether the third-option value increases or decreases choice accuracy. Given these opposing results, we sought to replicate and extend one study that reported a positive influence (Chau et al., 2014, Nature Neuroscience). Contrary to the results reported in the original study, however, we obtained a consistent negative relationship between choice accuracy and third-option value across four experiments with 147 participants. In-depth analyses of behavioral and eye-movement data revealed that high-value third options capture attention so that fewer cognitive resources are left to make accurate decisions. We propose a new computational model that accounts for the complex interplay of value, attention, and decision making. In this model, choice options are represented by leaky and mutually inhibiting accumulators that compete in a race-to-threshold manner. Fixations to choice options are modeled and influence the rate of accumulation. Most importantly, value-based attentional capture is implemented by coupling the probability of fixating an option with the option's value. Our model is able to reproduce the central patterns of our choice and RT data. Taken together, we provide an explanation of how choice sets and choice contexts influence the cognitive processes underlying human decision making.

Using Effective Connectivity to Test Computational Cognitive Models: It's Models All the Way Down (and it's a Good Thing!)

23/07 16:20
Tiered
Scarman

Andrea Stocco, Lauren Graham, Chantel Prat
University of Washington, United States of America

Computational models have often been used to interpret neuroimaging data. For example, both the transient activation of groups or layers of neurons in a neural network and the periods of resource utilization of difference modules in symbolic architectures can predict regional differences in observed brain activity.

While this approach is useful and profound, it stills falls short of taking advantage of the full range of predictions that computational models can make. For example, comparisons between neuroimaging data and model activity overlook the directionality of information processing. Models often make strong assumptions on how information passes through different components at different times. Indeed, this directionality is often necessary for the model to work properly, but is rarely tested.

While directionality cannot be directly estimated from neuroimaging recordings, it can be inferred using more complex analysis techniques, such as Granger causality

and dynamic causal modeling. As an example, we present the case of an ACT-R model that solves Raven's Advanced Progressive Matrices, a non-verbal test of fluid intelligence. Two versions of the model make identical predictions in terms of behavioral regional fMRI activity, but entail opposite views about the role of the basal ganglia in mediating the connectivity between prefrontal cortex and higher-level visual areas. An analysis of effective connectivity between the two regions reveals that the basal ganglia act by reducing, rather than increasing, the connectivity between the two regions, thus providing support for one version of the model and disproving the alternative.

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Modeling Mouse-Tracking Trajectories with Generalized Processing Tree Models

Daniel W. Heck, Edgar Erdfelder, Pascal J. Kieslich
University of Mannheim, Germany

Multinomial processing tree models assume a finite number of cognitive states that determine frequencies of discrete responses. Generalized processing tree (GPT) models extend this conceptual framework to continuous variables such as response-times, process-tracing measures, or neurophysiological variables. Essentially, GPT models assume a finite mixture distribution, where the weights are determined by a processing-tree structure, whereas continuous components are modeled by parameterized distributions such as Gaussians with separate or shared means across states. Using a simple modeling syntax, GPT models can easily be adapted to different experimental designs. We develop and test a GPT model for a mouse-tracking paradigm for a semantic categorization task, which is based on the feature comparison model (Smith, Shoben, & Rips, 1974). The model jointly accounts for response frequencies of correct responses and the maximum-deviation of mouse trajectories relative to a direct path.

23/07 16:20
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Scarman

Are Intertemporal Preferences Transitive? A Bayesian Analysis of Repeated Individual Intertemporal Choices

Junyi Dai
Max Planck Institute for Human Development, Germany

Transitivity of preferences is a central axiom of rational decision making. Previous research on intertemporal choice has suggested that intertemporal preferences might be intransitive, for which nonadditivity in delay discounting is one of the reasons. Most studies in this line of research have either analyzed aggregate data or ignored the probabilistic nature of intertemporal choice when addressing individual data. In this article, I present a refined experiment for studying transitivity of intertemporal preferences with repeatedly presented choice questions tailored to each individual participant. A Bayesian model comparison was applied to the individual choice data to test four stochastic models of transitivity: weak, moderate, and strong

stochastic transitivity, as well as a mixture model of transitive preference against the most general model allowing for all types of preference orders, and intermediate models accommodating nonadditivity in delay discounting. The results showed that individual data from a majority of participants were consistent with a transitive view of intertemporal preferences. In addition, nonadditivity in delay discounting - defined as special cases of violating weak, moderate, or strong stochastic transitivity - rarely occurred at an individual level. These findings provide critical information for developing and testing competing cognitive models of intertemporal choice.

Multialternative decision by sampling

23/07 16:40
The Slate

Takao Noguchi[1] and Neil Stewart[2]

[1] Queen Mary, University of London, [2] University of Warwick

Sequential sampling of evidence, or evidence accumulation, has been implemented in a variety of models to explain a range of multialternative choice phenomena. But the existing models do not agree on what, exactly, the evidence is that is accumulated. They also do not agree on how this evidence is accumulated. In this article, we use findings from process-tracing studies to constrain the evidence accumulation process. With these constraints, we extend decision by sampling model and propose the multialternative decision by sampling (MDbS) model. In the MDbS model, the evidence accumulated is outcomes of pairwise ordinal comparisons between attribute values. This MDbS model provides a quantitative account of the attraction, compromise, and similarity effects equal to that of other models, and captures a wider range of empirical phenomena than other models.

A model for the neural and mechanistic basis of self control

23/07 16:40
Tiered
Scarman

Brandon Turner[1], Christian Rodriguez[2], Qingfang Liu[1], Marjolein Hoogendijk[3] and Samuel McClure[4]

[1] The Ohio State University, [2] Stanford University, [3] University of Amsterdam, [4] Arizona State University

Intertemporal choice requires a mixture of valuation and self-control processes, and previous studies have implicated the contribution of several key brain areas in these types of tasks, yet their precise role has yet to be unraveled. Here we propose a model based on decision field theory where attention is allocated to separate attribute dimensions in a stochastic manner. In particular, the model takes the value of the rewards and delays of the two options as inputs, and probabilistically samples information on a moment-by-moment basis. This integration process creates a subjective representation of the smaller sooner and larger later options, where the relative contributions of reward and temporal delay within the subjective representations is determined by an attribute bias parameter. On top of the integration process are mechanisms such as lateral inhibition and leakage, which operate asymmetrically across the two options. In the model, these mechanisms mimic concepts

such as self control and impulsivity when operating in a goal-directed manner. By fitting a hierarchical version of the model to data from an intertemporal choice experiment, we found that the model provides a good account of choice and response time behavior. A whole-brain general linear model analysis revealed separate patterns of correlations between brain areas putatively associated with valuation or self control and the model parameters.

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Scarman

Tree Inference: Factors Selectively Influencing Processes in Multinomial Processing Trees with Response Times

Richard Schweickert, Xiaofang Zheng
Purdue University, United States of America

Multinomial Processing Trees (MPTs) are used to model response probabilities in a variety of psychological tasks, but response times in only a few. A vertex in an MPT represents a mental process. We discuss MPTs in which processing at a vertex results in selection of an arc descending from the vertex with some probability and requiring some time. After an arc is selected processing begins at a further vertex, or a response is made. An experimental factor, such as word-frequency, is said to selectively influence a vertex if changing the level of the factor changes probabilities and times for arcs descending from that vertex and no other. Suppose each of two factors selectively influences a different vertex in an arbitrary MPT. We show how to infer from patterns in the data an MPT that accounts for response probabilities and response times. But such an MPT is not unique. Two MPTs are equivalent if they predict the same response probabilities and response times for every combination of levels of the two factors. It turns out that an MPT accounting for the data is equivalent to one of two relatively simple MPTs. The two trees can readily be distinguished with empirical tests. Based on simulations, we discuss the power of the tests. For an MPT that accounts for the data, parameter values are not unique and we discuss how they can be transformed.

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Scarman

Informing cognitive models of self-control and impulsivity in intertemporal choice

Qingfang Liu, Per Sederberg, Brandon Turner
The Ohio State University, United States of America

The intertemporal choice requires an evaluation of a shorter sooner option (smaller reward but smaller delay) relative to a larger later option (larger reward but larger delay). Numerous studies have shown that subjects often perform in an inconsistent manner: sometimes making impulsive choices by rejecting the larger later option, and sometimes executing self-control by rejecting the shorter sooner option. Although previous research has shown that the deliberation process underlying intertemporal choice decisions can be well characterized by traditional sequential sampling models, it remains to be explored how self-control and impulsivity manifest in

this process. Some have proposed that self-control involves an amplification of the valuation of the larger later option, whereas others have proposed a goal-directed strategy without altering the valuation. To address this problem, we fitted a hierarchical diffusion decision model to data from an intertemporal choice experiment, where parameter estimates were derived for each trial. We explored the relationship between the distributions of parameters on trials where impulsive decisions were made relative to trials where self-control was executed. Ultimately, considering only behavioral data, we were unable to identify patterns of parameters that were unique to the concept of self-control or impulsivity. However, when looking at the BOLD response, a reliable signature corresponding to each decision was apparent. Considering the contradiction of behavioral and neural results, we investigated a series of joint models where the parameters explaining the behavioral data are driven by neural measures directly. The advantages and disadvantages of this integrative modeling approach are discussed.

Context-sensitive valuation during simple multi-alternative decisions

23/07 17:00
The Slate

Konstantinos Tsetsos[1] and Andrei Teodorescu[2]

[1] University Medical Center Hamburg, Germany, [2] University of Haifa

According to rational choice theory, the subjective value of an alternative is only a function of how well its properties match the goals of the decision-maker. However, behavioural experiments have repeatedly shown that humans evaluate alternatives in a context-dependent fashion. A hallmark of this context-dependence is the common tendency towards contextual preference reversal, that is changes of preference (e.g. switching from A to B) merely due to the presence or absence of other alternatives (e.g. C). Contextual preference reversal are typically obtained in multiattribute choice problems. Recently however, signatures of context-dependent valuation were obtained in choices among unidimensional alternatives. In particular, it was shown that the probability of choosing A (i.e. a high value alternative) over B (i.e. a lower value alternative) decreases as the value of an overall inferior alternative C increases. This so-called distractor effect was explained using a divisive normalisation model. Here, using new experimental data, we contrast divisive normalisation with an eliminate-then-decide two-stage dynamical model and find stronger support for the latter. According to this two-stage model, in the first stage, the three alternatives compete via lateral inhibition until the activity of one of them falls below an elimination threshold. In the second stage, the two remaining options continue to compete, until the activity of one of them breaches a decision threshold. These findings provide fresh mechanistic insights about the nature of context-dependent valuation during multi-alternative decisions.

Using Large-Scale Spiking Neural Networks to simulate MEG data of Associative Recognition

23/07 17:00
Tiered
Scarman

Jelmer Borst

University of Groningen, Netherlands, The

I will discuss how we used large-scale spiking neural networks to simulate associative recognition. Associative recognition is the important ability to learn that two items co-occur. In the current experiment participants first studied word pairs. In a subsequent test phase, they had to distinguish between target pairs, re-paired foils, and foils consisting of entirely new words. To make this distinction, participants did not only need to remember the words they learned, but also which words occurred together as a pair.

Although detailed symbolic models exist that account for behavior, fMRI, and EEG data, it remains unclear how associative recognition is performed at the neural level. To investigate this, we used the Neural Engineering Framework to simulate associative recognition with spiking neural networks that can process symbols (using a vector representation known as semantic pointers) and coordinate cognition through the basal ganglia (e.g., Eliasmith et al., 2012). The model goes through the established stages of a recall-to-reject model of associative recognition: perceiving the word pair on the screen, determining whether the encoded words are familiar, recollecting and representing the most similar word pair from memory, deciding whether this is the same pair as presented on the screen, and issuing a response.

Because the resulting neural network model is very complex (¿ 800,000 neurons) we use magnetoencephalographic (MEG) data to constrain the model (Borst et al., 2016). The model matches data in occipital, temporal, prefrontal, and motor cortices, and shows how the associative recognition process could be implemented in the human brain.

Pushing the limits of Precision Medicine: Use of Bayesian adaptive design optimization leads to highly rapid, precise, and reliable estimates of delay discounting rates

23/07 17:00
Space 43
Scarman

Woo-Young Ahn, Hairong Gu, Yitong Shen, Nathaniel Haines, Mark Pitt, Jay Myung

The Ohio State University, United States of America

As exemplified by the Precision Medicine initiative, there is a growing interest in how to apply computational tools/methods to the whole range of health and disease. Despite growing enthusiasm, we still have few rapid and reliable measures for characterizing mental disorders and associated phenotypes. Here we demonstrate that use of Bayesian adaptive design optimization (ADO) can lead to excellent test-retest reliability of delay discounting rates (k), which is a candidate endophenotype of addictive disorders.

College students participated in a delay discounting experiment, which consisted of four conditions. In two conditions, ADO and the hyperbolic function was used to

select delays and the amount of reward. In the other two conditions, a conventional staircase method was used. Participants returned for a second visit in approximately a month and completed the same experiment.

With ADO, we achieved over 0.96 test-retest reliability of k within each visit. The mean test-retest reliability between the two visits was 0.81 with ADO. The staircase method yielded lower within-visit (r=0.91) and between-visit (mean r=0.72) reliability. Each participant's k was far more precise (i.e., smaller SD) with ADO than with the staircase method. Remarkably, with ADO, the test-retest reliability quickly reached 0.95 or higher within 10-20 trials, but it slowly increased over trials and reached its peak after 35-40 trials with the staircase method.

These results demonstrate that we can quickly acquire reliable and precise delay discounting rates with ADO. This line of research could provide standardized and rapid protocols that can be integrated into clinical settings.

Hierarchical Bayesian Modeling of Information Integration and Sequential Consideration

23/07 18:00
The Slate

Joost Agelink van Rentergem, Nathalie de Vent, Tycho Dekkers, Laura Dekkers, Brenda Jansen, Ritte Olthof, Hilde Huizenga

University of Amsterdam, Netherlands

Background: In decision-making, people can base decisions on information from multiple sources. For some decisions, one's own information can be informative enough to base a decision upon. For other decisions, external sources of information have to be considered as well. In this study, we investigated whether participants integrate their own information and external information, or whether participants sequentially consider the different sources, only considering the external when their own information is insufficient. This was studied in multiple age groups to establish whether age determines the strategy used. Participants: 13 children, 30 adolescents and 26 adults. Methods: Participants performed an auditory discrimination task. In a second block, participants were also presented with a second, visual, stimulus that appeared on screen with the second tone. This visual stimulus, in the form of words "Higher" or "Lower", hinted at the correct answer. Participants were told beforehand that this visual stimulus was correct 75% of the time. Analysis: An "integrative" logistic model with interactions between the auditory and visual stimulus was compared to a "sequential" change-point logistic model. With the change-point, it was modeled how difficult the auditory discrimination trial needed to be before the participant changed from following one's own auditory perceptual information, to following the external visual information on the screen. Bayesian hierarchical estimation was used to allow individual differences in (a) the ability to perform the auditory discrimination task, (b) the ability to integrate the two sources and (c) the difficulty at which the own perceptual information was no longer used.

23/07 18:00
The Slate

One-to-one correspondence between competence and performance states in disjunctive skill functions

Pasquale Anselmi[1], Luca Stefanutti[1], Jürgen Heller[2] and Egidio Robusto[1]

[1] University of Padua, Italy, [2] University of Tübingen, Germany

In knowledge space theory, the competence structure is a collection of competence states (sets of skills possessed by individuals), and the performance structure is a collection of performance states (sets of items mastered by individuals). The existence of a one-to-one correspondence between the two collections is crucial for uniquely assessing the skills underlying the item responses. The talk presents properties of a disjunctive skill function (i.e., for all the items, each of the skills assigned to a certain item is sufficient for solving the item) that are sufficient, or necessary and sufficient for having the aforementioned one-to-one correspondence. The conditions are discussed in the light of several examples. Moreover, it is shown how to add items to the domain so that the skills are uniquely assessed.

23/07 18:00
The Slate

Do stimuli with different properties benefit differentially from testing?

William Aue, Jeffrey Karpicke

Purdue University, United States of America

When people learn during testing, what aspects of the encoded information are enhanced? For a word list experiment, there are multiple properties upon which words can be classified. Word frequency has a well documented and robust effect on memory performance. Likewise, context variability, quantified as the number of context with which a word is associated, also impacts memory performance. Yet the two properties would seem to tap distinct aspects of item characteristics. Despite the mountainous literature on testing effects, to the best of our knowledge no one has attempted to use word properties to elucidate mechanisms of the testing effect. Testing could interact with word frequency, potentially indicating that semantic/lexical encoding of words are impacted by testing. Testing could also interact with context variability, supporting the idea that testing impacts item to context associations. What we find is a more complicated story indicating that when context variability is held constant within a list, high frequency words benefited more from testing if the list was low variability. One potential explanation is that high frequency words benefited from testing more in the low variability list because testing facilitated better item to context associations. Additional results and implications for explanations of the testing effect and computational models of memory are discussed.

Cognitive approach to human-computer interaction projecting

23/07 18:00
The Slate

Arsenii Bakanov, Tatiana Savchenko, Galina Golovina
Institute of Psychology of Russian Academy of Sciences, Russian Federation

Study of user's cognitive characteristics, defining the patterns of human-computer interaction with information systems is an important issue of science. Some researchers assume that these are mostly cognitive styles that determine individual styles of information processing to a large extent, as they regulate affective and behavioral aspects of an individual. In particular, several studies which involved working on decision-making tasks (Witkin, Kholodnaya, etc.) show that analytics (the narrow-wide diapason of equivalence style the pole of narrowness) much more often rely on explicit and formal object features. On the contrary, synthetics (persons tending to the opposite pole of width) also take into account additional, implicit interdependencies between objects.

Research team of the IPRAS (FASO 0159-2017-0010 and supported by the RFBR via grant 15-07-01861) conducted experimental studies aimed to analyze the effects of user's cognitive style on the process of human-computer interaction. The sample mostly consisted of students and department employees.

Several cognitive styles have been studied: a) field-dependence/independence style; b) narrow-wide diapason of equivalence style; c) impulsiveness/reflexivity style. For assessing cognitive-stylistic characteristics several psychodiagnostic procedures have been conducted: 1)Included shapes test (Witkin), 2) Free object sorting test, 3. Similar drawings matching test.

Processing and analysis of the experimental study data allowed to find out statistically valid correlational interdependencies between cognitive styles with the effectiveness of interaction with information system. It has been proved that the success of human-computer interaction is mostly associated with narrow-wide diapason of equivalence style, and field-dependence/independence style.

New IRT Model Incorporating Response Time via Linear Ballistic Accumulation

23/07 18:00
The Slate

Kyosuke Bunji[1] and Kensuke Okada[2]
[1] Graduate school of Education, University of Tokyo, [2] Department of Psychology, Senshu University

Typical item response theory (IRT) models do not explicitly represent the cognitive process behind the observed response. On the other hand, the diffusion model (DM) is a well-known model of the cognitive process involved in observed responses. Based on DM, a diffusion-IRT model has been developed. IRT is typically applied to the educational test data in which the response time is long, such as more than 10 seconds. However, because DM is intended to represent very short response times in experimental psychology (normally less than one second), it may not be suitable for modeling the response time in educational tests. Meanwhile, the linear

ballistic accumulation (LBA) model is a newer cognitive model of response time that requires fewer assumptions than DM. In this study, we propose a new IRT model that models both the item response and response time by using the concept of LBA. The proposed model is more simple and efficient than the diffusion-IRT model, while the parameter settings of the proposed model are analogous to it. Our simulation study revealed that the proposed and existing diffusion-IRT models resemble each other closely in terms of rank correlation between the corresponding parameters. Moreover, the proposed model converged faster than the diffusion-IRT model. In real data analysis, the proposed model achieved better fit in terms of information criteria (WAIC and WBIC). Furthermore, by using automatic differentiation variational inference (ADVI), the proposed model was able to estimate the same point estimates much faster and more accurately than the diffusion-IRT model.

23/07 18:00
The Slate

Testing expected properties of Bayesian cue integration on exponential families that are closed under multiplication

Luigi Burigana, Michele Vicovaro
University of Padua, Italy

One reason why Bayesian models based on the Normal law are welcome in perceptual psychology is that they exactly fit three natural expectations in the area: when two stimulus factors are in conflict the resulting perceptual value lies between the values separately supported by those factors, the resulting value is closer to that supported by the more reliable factor, and the variance implied by the combined action of the factors is no greater than the variances implied by them separately. To what degree are these good qualities shared by Bayesian models based on probability laws other than the Normal one? We address this question by referring to exponential distribution families that satisfy closure under multiplication, which is a key characteristic of prior families in Bayesian models, and by distinguishing seven desirable properties, one concerning the mean, three the variance, and three the relationship between mean and variance. The distribution families we discuss are the Bernoulli, Geometric, Gamma (including Exponential), Beta, and Pareto families. In our poster, after defining "closure under multiplication" and specifying the seven desirable properties of the mean and variance, we summarize the results of our investigation in a table, having the distribution families in the rows and the desirable properties in the columns. The results in the table show that the probability laws examined are quite various in the degree to which they approximate the optimum performance of the Normal law, and reveal possible limits of Bayesian modeling in perceptual psychology.

Towards cognitive economics

23/07 18:00
The Slate

Leigh Caldwell
Irrational Agency, United Kingdom

The field of behavioural economics describes deviations from the purportedly optimal decisions between bundles of material goods that are the subject of classical economics. Both behavioural and classical economics neglect the utility that decision-makers gain from mental states and beliefs that are independent of physical goods.

In this talk I propose a cognitive model composed of a graph of representations of causal relationships between events, objects and rewards. I show that a reinforcement learning process under cognitive limitations can give rise to this graph, and that the structure and behaviour of the graph can explain agents' experiences of gaining utility from mental processes such as anticipation of consumption, or from the events and characters described in fictional narratives.

I discuss implications for economic theory and practice, and propose that economic models microfounded on cognitively realistic assumptions might provide greater explanatory power than either classical or behavioural economics: a discipline we might call "cognitive economics".

The role of dopamine in the exploration/exploitation trade-off

23/07 18:00
The Slate

Karima Chakroun[1], Antonius Wiehler[1], Florian Ganzer[2] and Jan Peters[3]

[1] Department of Systems Neuroscience, University Medical Center Hamburg-Eppendorf, Germany, [2] German Center for Addiction Research in Childhood and Adolescence (DZSKJ), University Medical Center Hamburg-Eppendorf, Germany, [3] Biological Psychology, Department of Psychology, University of Cologne, Germany

Decision-making in a dynamic environment often involves choosing between exploiting well-known options (e.g. your favourite ice cream) and exploring novel options (e.g. a new type of ice cream on the market). Dopamine, a neurotransmitter closely associated with reward-seeking behaviour, is thought to play an important role in regulating this trade-off between exploitation and exploration.

To study the role of dopamine in exploration and exploitation, we assessed choices and associated brain activity using fMRI in 31 male participants during a 4-arm bandit task under three drug conditions: (1) increased dopamine levels via L-dopa (150mg), (2) decreased dopamine levels via haloperidol (2mg), and (3) placebo. Subjects repeatedly chose between four options (bandits) with fluctuating reward values. Maximizing pay-offs entails a trade-off between exploiting the currently best option and exploring alternative options. Choice data were analysed using hierarchical Bayesian cognitive modeling in order to quantify explore/exploit behaviour and apply these results to a model-based fMRI-analysis.

Results show that choice behaviour is best accounted for by a model that combines a Bayesian learner (Kalman filter model) with a softmax choice rule including

an explicit exploration bonus that scales with the estimated uncertainty of a bandit's outcome. More importantly, exploration bonus was the only model parameter sensitive to the drug manipulation, with attenuated exploration in L-dopa vs. placebo. Our data provide evidence for a causal role of dopamine neurotransmission in the regulation of the exploration/exploitation trade-off.

23/07 18:00
The Slate

The Impact of Presentation Order on the Attraction Effect in Decision-making

Aneesha Dasari, Jennifer Trueblood
Vanderbilt University, United States of America

The attraction effect in decision-making is a famous example of how preferences are influenced by the availability of other options. One emerging hypothesis for the effect is that biases in attention influence preferences. In the past, these ideas have been explored indirectly through computational modeling and eye tracking. In the present paper, we directly manipulate attention through presentation order, presenting choice options sequentially. Our results show that presentation order has a large impact on the effect: some presentation orders enhance the effect and other orders reverse the effect. To understand these results, we fit a dynamic model, called the Multiattribute Linear Ballistic Accumulator model, to the choice and response time data. Modeling results reveal that presentation order influences the allocation of attention on the positive and negative differences between options. In sum, our results show that attention has a direct impact on the attraction effect.

23/07 18:00
The Slate

Testing the fit of BLIM-like models with missing data

Debora de Chiusole, Pasquale Anselmi, Luca Stefanutti, Egidio Robusto
University of Padua, Italy

To date, a number of statistical techniques for dealing with missing data were developed, in order to obtain unbiased parameter estimates. Nevertheless, little attention was given to consequences of missing data on the model fit. In the present research, this issue is addressed in knowledge space theory (KST) framework. In KST three types of probabilistic models for missing data were developed: the IMBLIM, the MAR-BLIM and the MissBLIM. The first two are adequate when the process that generated the missingness is ignorable, thus the missing data are not considered in parameter estimation. The MissBLIM is suitable when the missingness process is non-ignorable, thus the missing data are parameterized. Previous works on these models showed that if the missingness is correctly treated the model's parameters are indeed unbiased. However, nothing was discussed about how the fit of these models should be tested. A method for testing the fit of the IMBLIM and the MAR-BLIM is proposed. It consists of computing a likelihood ratio test between the model of interest and a saturated model for complete data estimated on incomplete data.

The estimation is obtained via an application of the expectation-maximization algorithm. A number of simulation studies showed that the proposed procedure is adequate when the fitted model is the one generated the data. However, an undesirable result also arises: as the number of missing data increases the model fit improves, leading to situations in which a misspecified model can be accepted. Some suggestions for dealing with this impasse are discussed.

A database of ACT-R models of decision making

23/07 18:00
The Slate

Cvetomir M. Dimov[1], Julian N. Marewski[1] and Lael J. Schooler[2]
[1] University of Lausanne, Switzerland, [2] Syracuse University

http://www.ai.rug.nl/~mkvanvugt/ICCMprogram_files/paper_11.pdf

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Breaking the Vicious Limit Cycle: Addiction Relapse-Recovery as a Fast-Slow Dynamical System

23/07 18:00
The Slate

Jacob P. Duncan, Teresa M. Aubele-Futch
Saint Mary's College, United States of America

All drugs of abuse mimic natural neurotransmitter molecules and indulgence in these substances triggers a deluge of dopamine (DA) which leads to a state of euphoria and satiates cravings. Alcohol affects DA pathways in the brain's reward system by blocking gamma-aminobutyric acid (GABA) inhibition of DA neurons, effectively causing the release of excessive amounts of DA. To counteract this surplus, the brain increases production of enzymes that break down DA. Upon abstention from alcohol, the excess of these enzymes causes severe depletion of DA which leads to a state of anxiety/depression and fuels craving, ultimately precipitating a relapse. Hence, symptoms of addiction often manifest as periodic episodes of sudden relapse followed by long periods of recovery. To better understand the mechanisms driving relapse-recovery cycles, we construct a fast-slow dynamical system model of the interaction between DA and GABA in the brain of an alcoholic. The model captures the dynamics of addiction relapse and recovery by admitting a limit cycle. We derive an approximation of the cycle period to measure relapse frequency by exploiting time-scale separation. As a parameter identified as being responsive to treatment is varied, the system transitions from a state of periodic relapsing to a relapse-free state through Hopf bifurcation. We calculate the threshold value of the treatment parameter, which corresponds to the equilibrium point passing through the fold of the critical manifold. Our predictions of relapse frequency and threshold agree well with alcohol relapse data and may help inform addiction psychologists in refining treatment methods.

23/07 18:00
The Slate

Modelling Simple Ship Conning Tasks

Bruno Emond, Norman G. Vinson
NRC—CNRC, Canada

http://www.ai.rug.nl/~mkvanvugt/ICCMprogram_files/paper_38.pdf

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23/07 18:00
The Slate

A Bayesian framework to mitigate publication bias in meta-analyses

Alexander Etz, Joachim Vandekerckhove
University of California, Irvine, United States of America

Bayesian bias correction is a novel method for evaluating evidence in published papers in the presence of publication bias. The original method by Guan and Vandekerckhove (2016) is limited to single studies and sets of studies with homogeneous effect sizes. We develop an hierarchical extension of the method in order to allow for heterogeneous effect sizes, so that it may be used in a broader meta-analytic context. This extension dramatically increases the applicability of the method.

23/07 18:00
The Slate

Mathematical models of multi-level categorization and decision making processes

Iliana Mairen Fernandez-Roldan, Alfonso Diaz-Furlong
Benemerita Universidad Autonoma de Puebla, Mexico

In the past two decades several models have been proposed to give a description and an explanation to different cognitive processes, in particular, processes involving categorization and its interaction with the process of decision making. Two important papers, but in different frameworks, give a solution to the categorization-decision making interaction. The first one using a markovian approach by Townsend et.al. and the second one by J. Busemeyer et.al where they applied a non classical approximation that resembles the mathematics used in quantum mechanics. Following this two papers we found that these interactions between categorization and decision making processes remain open. In this poster we present a general model of categorization and decision making from a multi-level perspective (5-3 categorization-decision making model) and using markovian models, non classical models as well as a path integral approach. We are going to present the generation of the stimuli using the software Facegen and the analysis in Maple. We constructed a four group design where we controlled the outcomes of the history and the treatments. We found some interest results related to the interference between the processes, that going to be presented. One important result is that the participants tend to be constrained to the categorization levels when these are presented, compared when the categorization is absent making their decisions more complex.

Discriminating between conflict and value in foraging-like tasks: a sequential sampling-based approach

23/07 18:00
The Slate

Laura Fontanesi[1], Sebastian Gluth[2] and Amitai Shenhav[3]

[1] University of Basel, Switzerland, [2] University of Basel, Switzerland, [3] Brown University, USA

Foraging is a form of sequential decision-making under risk, where the the exploration of new options stands in tension with the exploitation of a default-option whose value decreases with time. Typically, the choice of exploring is made shortly after the point of maximal conflict (i.e., between staying and leaving) has been reached. For this reason, research into the mechanisms of foraging has difficulty dissociating the role of foraging value versus choice conflict in driving dorsal anterior cingulate cortex (dACC) activity during foraging (Kolling, Wittmann, Behrens, Boorman, Mars, & Rushworth, 2016; Shenhav, Straccia, Cohen, & Botvinick, 2016). Using a novel foraging-like task, Meder and colleagues (2016) recently offered support for foraging value rather than choice conflict as an explanation for dACC activity. We replicated Meder et al.'s study in order to (1) assess how suitable the task is for discriminating between conflict and value theories of dACC involvement in foraging and (2) offer a simultaneous account of choices and response times, using sequential sampling models. Our findings suggest that this task is not suitable for discriminating between conflict and value, as conflict and value are highly correlated, and this correlation increases with risk-seeking behavior. Furthermore, we were able to fit different hierarchical bayesian diffusion decision models (DDM), which predict higher response times with higher response conflict, but differ in how parameters are modulated by the accumulated resources. Finally, we were able to devise a new version of this task which can produce the desired decrease in correlation between conflict and value.

Non-local influences on associative learning: new data and further model evaluation

23/07 18:00
The Slate

Steven Glautier

Southampton University, United Kingdom

Previous work (Glautier, 2013) showed that the responses made by humans on trial n in simple associative learning tasks were influenced by events that took place on trial n1 and a simple extension of the Rescorla-Wagner Model (RWM Rescorla & Wagner, 1972), the Memory Environment Cue Array (MECA) model was presented to account for those results. In the current work further evidence of non-local influences on responding during associative learning tasks is presented. The Rescorla-Wagner model and the MECA model are evaluated as models for the observed data using qualitative, naive maximum likelihood, and Akaike weight analyses. In two experiments the Akaike weight analyses strongly supported the simpler Rescorla-Wagner model over the MECA model but the qualitive and naive maximum likelihood analyses strongly supported the MECA model model over the simpler Rescorla-Wagner model. In Experiment 2 this apparent conflict was resolved using a generalisation

test (Ahn, Busemeyer, Wagenmakers, & Stout, 2008; Busemeyer & Wang, 2000) which gave clear support to the MECA model over the Rescorla-Wagner model. These results demonstrate the superiority of model selection using predictive validity, where possible, over selection using statistical adjustments for model complexity.

23/07 18:00
The Slate

Sequential effects: resonance with oscillators?

Dinis Gokaydin
University of Warwick, United Kingdom

Human reaction times depend on the previous sequence of trials, even if the sequence is random, a phenomenon known in the literature as 'sequential effects'. Such effects are thought to be related to a sensitivity to local - i.e. in the past few trials - patterns in the sequence, in particular randomly occurring runs of alternations or of repetitions. Most mathematical models of sequential effects are discrete-time in nature and consist of combinations of one or more types of Markov chain with exponential 'forgetting' of past events. However, the time interval between successive stimuli has been shown to be of paramount importance to sequential effects, indicating that a continuous-time model is necessary. A few continuous-time models have been suggested previously but are unable to represent spatial location, also found to be of crucial importance in sequential effects. Here I present a new modelling platform based on the physics of oscillations which - albeit still preliminary - has the capacity to represent all relevant aspects of sequential effects. Furthermore, an extension of the model into nonlinear oscillations and spatio-temporal pattern formation becomes a natural step and - according to some evidence I will present - sequential effects might be related to the detection of repeating and alternating patterns both in time and space.

23/07 18:00
The Slate

Buggy rules in quantitative reasoning

Matthias Gondan
Faculty of Psychology, University of Vienna, Austria

I present an E-Learning tool that anticipates and detects buggy reasoning in quantitative problem solving. The system can then provide feedback for specific mistakes that underlie the erroneous solutions. For example, some students forget the (implicit) parentheses around the numerator and denominator of fractions, so that a fraction like $\overline{X} - \mu$ in the numerator and $s/\sqrt{N}$ in the denominator is incorrectly calculated as $\overline{X} - (\mu/s)/\sqrt{N}$ because "$\overline{X} - \mu/s/\sqrt{N}$" is linearly typed into the calculator. More abstract buggy rules include the use of irrelevant variables as predictors in regression models, wrong statistical tests, or inadequate handling of missing data. Such mistakes follow their own logic, so that they can be implemented as Prolog rules (Colmerauer and Roussel, 1996), combined and recognized by a computer system (e.g., Zinn, 2006). By extending the elementary algebraic functions as well as

typical statistical procedures, the system can diagnose a potentially huge set of students' answers. The Prolog interpreter is embedded as a library ("Rolog") into the R statistical language system (R Core System, 2017) which enables the simultaneous use of a declarative and imperative programming language.

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Need for Achievement in Innovators: Comparison of Mathematical Models

23/07 18:00
The Slate

Vera Gryazeva-Dobshinskaya, Yulia Dmitrieva

South Ural State University, Russian Federation

Modeling need for achievement (nAch) in innovators is necessary to predict success in operations. Need for achievement was considered a motivational resource of innovators activity with diverse trends: innovative (including indicators of "pure hope", "hope for success" need) and stabilizing (including indicators of "general achievement motivation", "avoiding failure" need).

The purpose of research was to compare mathematical nAch models in order to identify innovators with maximal motivational activity resources and subsequent division of innovators into groups. The psychological test on motivational activity resources was carried out with the help of H. Hekhausen's method. The research involved 322 managers of Ural companies.

The mathematical modeling was based on a system of two linear equations. The coefficients are equal to the values of psycho-diagnostic indicators of motivational resources of manager. Mathematical models of "cooperation" and "competition" were used taking into account the type of interaction between the indicators. Solving the system of equations helps us to determine the coordinates Ym and Xm, which are integral indicators of trends activity for each model.

Three options of dividing managers into groups were considered: by ratio of psycho-diagnostic indicators; by ratio of integrated indicators based on "cooperation" and "competition" models. Using discriminant analysis, the proposed classification of innovators into groups was checked for correctness. It was found that the division of innovators according to the integrated indicators based on the "competition" model gives the most accurate reference of an innovator to a certain group, and the minimum if judged by the ratio of psycho-diagnostic indicators.

23/07 18:00
The Slate

A Comprehensive Model Comparison in Intertemporal Choice

Lisheng He[1], Marc Scholten[2], Kenneth Lim[1], Adam Sanborn[1] and Daniel Read[1]

[1] University of Warwick, Coventry, United Kingdom, [2] Universidade Europeia, Lisbon, Portugal

Model comparisons in intertemporal choice have suffered from three main limitations: Model selectivity, stochastic-specification selectivity, and stimulus diversity. Core models, stochastic specifications, and designs of stimuli varied substantially across studies, which threatens the comparability of past results. In this study, we compared 15 intertemporal choice models across 225 data sets, with three stochastic specifications (Luce's, Logit and Probit choice rules), to establish whether past data convey a coherent message about the psychology of intertemporal choice. The core models include eight alternative-based models (including Exponential, Quasi-Hyperbolic, Hyperbolic, Generalized Hyperboloid [Mazur, 1987], Generalized Hyperboloid [Loewenstein & Prelec, 1992], Constant-Sensitivity, Double-Exponential and Generalized Hyperboloid [Scholten, Read, & Sanborn, 2014]), six attribute-based models (including Proportional Difference [PD], Intertemporal Choice Heuristics [ITCH], Difference-Ratio-Interest-Finance-Time [DRIFT] and three variants of the tradeoff model) and one hybrid model (Discounting by Interval). The data sets were compiled from 97 published and unpublished papers and further screened with a baseline model to select the data sets that were informative enough for model selection. Results from this comprehensive model comparison lend strong support for the class of attribute-based models, especially the family of tradeoff models. Furthermore, interactions between models and stochastic specifications were observed, highlighting the importance of the choice of stochastic specifications for intertemporal choice modeling.

23/07 18:00
The Slate

Bayesian generalized partial credit type model of anchoring vignettes: Are latent response categories evenly spaced?

Daiki Hojo, Kensuke Okada

Senshu University, Japan

A multidimensional item response theory (IRT) model of anchoring vignettes has been proposed recently. This model measures and controls for the individual differences in response styles to survey questions. One of the key assumptions behind this model includes evenly-spaced latent response categories of a scale. This corresponds to the case in partial credit model in the context of IRT literature, and thus is called the PC-based model. However, this assumption may not hold in many real-world applications, and the Survey of Health, Ageing and Retirement in Europe (SHARE) is no exception. In the SHARE dataset, the most selected response category for the anchoring vignettes items is the first category. This may lead to a biased result when it is analyzed with the PC-type model. Therefore, we adopted a fully Bayesian approach, and proposed a generalized partial credit (GPC) type model, which freely

estimates the intervals between the response categories in addition to measuring and controlling for the response styles. We first compared the performance of GPC- and PC- based models by a Monte Carlo simulation study. The results were evaluated in terms of both the posterior predictive checking and other relative measures of model fit. Then, we applied the proposed GPC-based model to the SHARE dataset. The utility of the GPC-based model of anchoring vignettes in psychology was discussed.

The interaction of input structure and cognitive architecture in a model of semantic development

23/07 18:00
The Slate

Philip Huebner, Jon Willits

University of California, Riverside, United States of America

How does the order in which children learn about words affect semantic development? Specifically, how does the initially simple, and later increasingly complex nature of child-directed speech impact semantic development trajectories? We investigated this question by training two variants of recurrent neural networks - Long Short Term Memory models (LSTMs), and Simple Recurrent Networks (SRNs) - on a naturalistic language sequence prediction task using child-directed speech (the CHILDES corpus). The input to these models was manipulated in two ways. First, we tested whether models trained on age-ordered sequences of CHILDES documents learned better than networks trained on documents whose order was randomized. Second, we tested whether training curricula with local iterations over the input (modeling the cognitive system's consolidation over smaller portions of input) learned better than models experiencing passes over the full training corpus (as neural networks are typically trained, despite the lower cognitive plausibility of such methods). Neither manipulation affected the networks' ability to predict word sequences. However, when the model's internal representations were used in a semantic classification task, we found that training with iterations over small portions of chronologically-ordered input significantly improved semantic classification for the LSTM (but not the SRN). These results suggest that the development of semantic representations may be benefiting from an optimal alignment of environmental structure, and structure of the learning and memory system. Input to children tends to start simple and gradually increase in complexity, and this is best learned by a system that consolidates over relatively small portions of the input.

Uncertainty surrounding best fit in probabilistic learning tasks

23/07 18:00
The Slate

Dominic J. M. Hunt, Alan D. Pickering
Goldsmiths University, United Kingdom

Our brains update their understanding of the world around them based on the relationship between their expectations and what they observe. Mathematical models of action-reward or stimulus-reward sequences allow us to explore the underlying mechanisms.

A wide range of Bayesian and reinforcement learning models have been proposed to account for features of how the brain learns from rewards. To keep explanations clear, presented models are often stripped of unrelated capabilities. In so doing, they do not address the capacity of the models to be extended, nor how this would affect their performance. Comparing the performance of models can also be difficult with so many different criteria used.

We present a method of comparing such models, evaluating their performance, in a consistent and normalised way, across probabilistic reward learning experiments with both a fixed stimulus and a varying number of simultaneous stimuli. We do so using a testing framework that allows us to swap models and experiments independently. Using this, we look at the performance and characteristics of these models in both simulated data and real participant data. We show that for some types of tasks, there is a plateau region of model fit, encompassing the best fit, in which a wide variation in parameter values produces little change in the overall model fit. We consider the implications of this observation. Using simulated data, we show how these plateau regions relate to the parameters used to generate the simulated data, along with how the regions vary for the same parameters.

Fitting a hierarchical Linear Ballistic Accumulator model to response time data collected both online and offline

23/07 18:00
The Slate

Takahisa Ikeda, Kensuke Okada
Senshu University, Japan

In recent years, the number of psychological studies that collect data online, as opposed to the laboratory, is increasing. Chetverikov & Upravitelev (2016) conducted a simple visual search task, both online and in the laboratory, and investigated differences in response time found between the two experimental conditions. For this purpose, they resorted to two approaches: visual comparison of empirical response time distributions and an analysis of variance (ANOVA). Their results suggest that, although the distributional shape is similar, the mean response time differs between the conditions. However, these approaches are not optimal for representing a data generating mechanism and investigating individual differences in response time. Therefore, in this study, we constructed a hierarchical Bayesian linear ballistic accumulator (LBA) model that takes into account the cognitive mechanism of data generation and individual differences. Then, we fitted the model to the

data obtained in the previous study using the Markov chain Monte Carlo algorithm. Results indicate that the drift rate parameter tends to increase as the set size in experiment increases, which is in line with the previous finding. Results also indicate that individual differences are larger in non-decision time parameter as compared to other parameters. This suggests that the differences in an individual's response time may be related to differences in the encoding and motor process.

Model Predictions of Reward Optimization in Discrete Dual-Task Scenarios

23/07 18:00
The Slate

Christian P. Janssen, Emma Everaert, Heleen M.A. Hendriksen, Ghislaine L. Mensing, Laura J. Tigchelaar, Hendrik Veere Weermeijer
Utrecht University, Netherlands, The

http://www.ai.rug.nl/~mkvanvugt/ICCMprogram_files/paper_3.pdf

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Modelling the role of grammatical functions in language processing

23/07 18:00
The Slate

Stephen Mark Jones
University of Oxford, United Kingdom

http://www.ai.rug.nl/~mkvanvugt/ICCMprogram_files/paper_39.pdf

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Social Laser in action: from color revolutions to Brexit and Donald Trump

23/07 18:00
The Slate

Andrei Khrennikov
Linnaeus University, Sweden

This is the conceptual paper aimed to present the basic assumptions for creation of social lasers and attract attention of other researchers to the problem of modeling of Stimulated Amplification of Social Actions (SASA). The model of SASA and its analysis are based on the mathematical formalism of quantum thermodynamics and field theory (applied outside of physics). The presented quantum-like model provides the consistent operational model of such complex socio-psychological phenomenon as SASA. The present model is heavily based on the use of the notion of social energy. This notion has not yet been formalized. Evidence of SASA ("functioning of social lasers") is rapidly accumulating, from color revolutions to such democratically structured protest actions as Brexit and the recent election of Donald Trump as the president of USA. The corresponding socio-political and psychological studies are characterized by diversity of opinions and conclusions. The presented social laser model can be used to clarify these complex socio-political events and even predict their possibility. SASA is the powerful source of social instability. Understanding its informational structure and origin may help to stabilize the modern society. Application of the quantum-like model of laser technology in social and political sciences is really novel and promising approach.

23/07 18:00
The Slate

Planning Beyond the Next Trial in Adaptive Experiments: A Dynamic Programming Approach

Woojae Kim[1], Mark Pitt[2], Zhong-Lin Lu[2] and Jay Myung[2]

[1] Howard University, United States of America, [2] The Ohio State University, United States of America

Experimentation is at the heart of scientific inquiry. In the behavioral and neural sciences, where only a limited number of observations can often be made, it is ideal to design an experiment that leads to the rapid accumulation of information about the phenomenon under study. Adaptive experimentation has the potential to accelerate scientific progress by maximizing inferential gain in such research settings. To date, most adaptive experiments have relied on myopic, one-step-ahead strategies in which the stimulus on each trial is selected to maximize inference on the next trial only. A lingering question in the field has been how much additional benefit would be gained by optimizing beyond the next trial. A range of technical challenges has prevented this important question from being addressed adequately. This study applies dynamic programming (DP), a technique applicable for such full-horizon, 'global' optimization, to model-based perceptual threshold estimation, a domain that has been a major beneficiary of adaptive methods. The results provide insight into conditions that will benefit from optimizing beyond the next trial. Implications for the use of adaptive methods in cognitive science are discussed.

23/07 18:00
The Slate

A joint evaluation of list length and list strength effects in recognition memory

Asli Kilic

Middle East Technical University, Turkey

There has long been a debate on whether increasing the number of study items decrease accuracy in episodic memory. In item-noise models, additional memory traces cause interference and consequently observed as a decrease in hit rates and an increase in false alarm rates. Although, earlier studies showed null list length (LLE) effects when possible confounding variables were controlled (e.g., Dennis, Lee, & Kinnell, 2008), the current study presents a LLE when items are strengthened in pure lists even when the confounding variables are controlled. In a series of experiments, list length was manipulated across strong and weak lists where strength was manipulated via repetition or a levels-of-processing task. The results showed a LLE when items were strengthened in pure lists but not when items were strengthened in mixed lists. The implications of these findings for memory models will be further discussed.

Conceptual Approach to Model the Effects of Feedback on Mental Model Activation

23/07 18:00
The Slate

Oliver W. Klaproth, Nele Russwinkel

Technical University Berlin, Germany

http://www.ai.rug.nl/~mkvanvugt/ICCMprogram_files/paper_14.pdf

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Sentence acceptability judgment: task assumptions, reliability, and sample size

23/07 18:00
The Slate

Steven Langsford[1], Lauren Kennedy[1], Andrew Hendrickson[1], Daniel J. Navarro[2] and Amy Perfors[1]

[1] The University of Adelaide, Australia, [2] The University of New South Wales

This project presents an original application of Thurstonian modelling to sentence acceptability judgment, and compares the results with commonly used elicitation methods (Likert scales, magnitude estimation, and forced choice) in terms of cross-measure agreement and test-retest reliability at varying sample sizes.

Contrasting diverse measures on the same set of sentences shows how sensitive results are to assumptions imposed by each. We find that despite their drastically different assumptions, Likert ratings and Thurstonian acceptability estimates are highly consistent, suggesting that plausible objections to the specific assumptions made by each are not limiting in practice. Contrasting between and within participant test-retest reliability shows the extent to which the different tasks are sensitive to individual differences and item neighborhood effects, which contribute to between-participant variability only. We find that the different measures are differently vulnerable to these sources of variation, with magnitude estimation particularly sensitive. Contrasting varying sample sizes shows the relative efficiency of each method. We find that targeted forced-choice comparisons have extremely high power, but are also more likely than other methods to include sign errors among the differences identified. Taken together, these results help show not just that these methods for measuring sentence acceptability are different, but how and why they are different.

Effect of Speed-Accuracy Manipulations on Nondecision Time: Lack of Discriminant Validity of the Manipulation or the Parameter Estimation? A Simulation Studies based on the Diffusion Model

23/07 18:00
The Slate

Veronika Lerche, Andreas Voss
Heidelberg University, Germany

Several experimental validation studies have been conducted to test the validity of the parameters of the diffusion model. To assess the validity of the threshold separation parameter, typically speed-accuracy manipulations are employed. The common finding is a good convergent validity of the threshold separation with lower values under speed in comparison with accuracy settings. However, often also effects in nondecision time have been found: Estimates for nondecision time are lower under speed than accuracy settings. We examined whether this finding can be attributed to a lack of discriminant validity of the experimental manipulation or to trade-offs in parameter estimation. To this aim, we conducted simulation studies based on parameter sets observed in experimental studies. Our results indicate that the effects of speed vs. accuracy instructions on nondecision time are mainly attributable to a lack of discriminant validity of the experimental manipulation rather than to problems in the parameter estimation.

Modeling visual search processes using Markovian queueing models

23/07 18:00
The Slate

Yiqi Li
University of Mannheim, Germany

Concerning the serial/parallel debate in the visual attention literature, Moore and Wolfe (2001) outlined a hybrid model which can conceptually accommodate existing, conflicting empirical findings supporting either the serial or the parallel account. To formalize computational testable models based on the conceptualization of Moore and Wolfe, I proposed to model visual search processes using Markovian queueing models (Li, 2016). The proposed family of models considers the temporal issues of discrete information transmission to account for response time distributions in visual search experiments. In this framework, visual processing is viewed as a queueing system where visual stimuli enter and leave serially, but are processed in parallel; the system triggers a response when the 'service' of the target or the last stimulus is finished. More precisely, models for finite queueing systems with exponentially distributed inter-arrival times and service times, servers, waiting room capacity, customers and default rule 'first come, first serve' (M/M/c/k/k/FCFS) are specified. Simulations show that these models possess several desirable properties: They can generate system response time data mimicking the reaction times observed in various types of visual search experiments (Wolfe, Palmer & Horowitz, 2010) in distribution; they can reproduce several patterns reliably found in empirical data across different

experimental conditions; varying model parameters (e.g. inter-arrival rate) selectively has a similar effect on the mean of the simulated data to those an experimental manipulation (e.g. perceptual difficulty) exerts on observed reaction times.

Modeling Relational Reasoning in the Neural Engineering Framework

23/07 18:00
The Slate

Markus Lohmeyer, Julia Wertheim
Albert-Lurdwigs-Universität Freiburg, Germany

http://www.ai.rug.nl/~mkvanvugt/ICCMprogram_files/paper_19.pdf

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An Ising model for affect dynamics

23/07 18:00
The Slate

Tim Loossens, Francis Tuerlinckx, Stijn Verdonck
KU Leuven, University of Leuven, Belgium

Despite a vast amount of theoretical and empirical research, there is still a large degree of isolation between the study of the neurobiology and the psychology of affect. We propose a neurobiologically inspired computational model to bridge this explanatory gap. The model is based on the emerging collective behavior of pooled populations of stochastic binary neurons, which excite one another within a pool and typically inhibit one another between pools (comparable to the Ising Decision Maker in choice RT). It can naturally account for nonlinear dynamical and non-dynamical features, such as bimodalities, metastable states, and sudden transitions, features which are observed in affective data samples. In this talk, we will explain the model and how it relates to different experimental paradigms. We will then apply the model to a controlled experiment in which participants play a gambling game (and in which the emotional stimuli are quantifiable).

A Method to Systematically Find Better Cognitive Models: Conditional Reasoning as an Example

23/07 18:00
The Slate

Daniel Lux, Marco Ragni
University Freiburg, Germany

http://www.ai.rug.nl/~mkvanvugt/ICCMprogram_files/paper_20.pdf

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23/07 18:00
The Slate

Cognitive Modeling of Cardiopulmonary Resuscitation Knowledge and Skill Spanning Months to Years

Sarah Maass[1], Florian Sense[1], Matthew Walsh[2], Kevin Gluck[3] and Hedderik van Rijn[1]

[1] University of Groningen, Netherlands, The, [2] TiER 1 Performance Solutions Pittsburgh, Pennsylvania, [3] Air Force Research Laboratory Wright-Patterson Air Force Base

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23/07 18:00
The Slate

Testing Core Properties of Recognition-Memory Models: Ranking Judgments are Consistent with Two-High-Threshold Theory

Simone Malejka, Daniel W. Heck, Edgar Erdfelder

University of Mannheim, Germany

In a recent study, Kellen and Klauer (2014) used a K-alternative ranking task to compare continuous-strength and discrete-state models of recognition memory under minimal assumptions. The conditional probability of old items being assigned Rank 2 (given that they were not assigned Rank 1) was higher for strong than for weak old items. This finding was interpreted as being consistent with signal-detection theory, while contradicting the two-high-threshold model. According to the latter, failure to assign Rank 1 to an old item can be seen as evidence for entering a state of non-detection. Conditional on non-detection, the model apparently cannot explain how the strength of old items (weak vs. strong) can affect the ranking judgments. We first show that this conclusion only holds under the auxiliary assumption that new items are detected as new with the same probability in the context of weak versus strong old items. We then show that (a) the conditional probability of old items being assigned Rank 2 increases with the probability of new-item detection when the assumption is dropped, that (b) a model-based analysis of ranking judgments yields different probabilities of new-item detection for weak versus strong old items (Experiment 1), and that (c) new items are more easily detected in the presence of a strong than a weak old item, even when the old item was not detected (Experiment 2). Hence, Kellen and Klauer's (2014) finding is consistent with the two-high-threshold model as long as different probabilities of new-item detection are taken into account.

A utility model reflecting nonconstant impatience in intertemporal choice

23/07 18:00
The Slate

Yutaka Matsushita
Kanazawa Institute of Technology, Japan

In intertemporal choice, it has been found that if the receipt time is closer to the present, then people tend to grow increasingly or decreasingly impatient. The former or latter situation is recognized as increasing impatience or decreasing impatience, respectively. This study develops an axiom system to construct a weighted additive model reflecting nonconstant impatience. Presupposing that an increment di in duration is subjectively assessed when advancing the receipt of an outcome a from the previous i period to the previous i-1 period, we express the advanced receipt of a as ((ad1))dn. Then our utility model is of the form

u(((ad1))dn)=(w(d1)w(dn))u(a), w(di)$\geq$ 1,

where u is a function that represents preference for outcomes and w is a weight function. This model is constructed as follows. First, the conditions for enabling right multiplication by subjective increments are proposed on the Cartesian product of a generalized extensive structure and a set of durations. Second, the properties derived under these conditions yield a right action on the generalized extensive structure. Third, the weighted additive model is obtained as a representation of the generalized extensive structure equipped with the right action. Moreover, noting the fact that if the subjective increment di is assessed by a logarithmic scale, then the exponential discount function is transformed into the generalized hyperbolic discount function, we show that our model reduces to the exponential discount function under several conditions.

Prepaid parameter estimation without likelihoods

23/07 18:00
The Slate

Merijn Mestdagh, Francis Tuerlinckx
KU Leuven, Belgium

The estimation of parameters of statistical models constitutes an important part of today's scientific practice. In fields dealing with complex models for which no straightforward analytic expression exists, parameter estimation often comes with a substantial computational burden (e.g., extensive Monte Carlo simulations). Different individual model users are likely to perform a number of quasi identical or at least very similar computations however, all independent from each other. Each of these individual search procedures could benefit from the calculations performed in every other. Instead of focusing on improving the estimation process for a single user, we propose a pooling of resources. Starting from a massive random sample of parameter values, we generate for each parameter set, a very large data set under a given model. Next, we condense these data sets into summary statistics, thereby creating a giant look-up database. Combined with efficient interpolation techniques, this database can then be used to solve any individual estimation problem in a fraction of the time that is traditionally required (because the bulk of the computational

effort is prepaid). To demonstrate the efficacy of the method, databases were developed for three challenging estimation problems, such as the estimation of the parameters of the leaky competing accumulator diffusion model for choice RT data. Although a considerable one-time computational cost was invested in their creation, they can now be distributed as information, free of computational cost. It is shown through extensive simulation studies that our method greatly outperforms current individual estimation techniques in both speed and accuracy.

Bayesian network model for human performance assessment using virtual environments

23/07 18:00
The Slate

Allison Moyle, Mashrura Musharraf, Jennifer Smith, Brian Veitch, Faisal Khan
Memorial University, Canada

http://www.ai.rug.nl/~mkvanvugt/ICCMprogram_files/paper_30.pdf

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The problems of estimating drift diffusion models with simulations and a robust alternative

23/07 18:00
The Slate

Timothy L Mullett
University of Warwick, United Kingdom

Drift Diffusion Models (DDMs) are being applied to numerous domains. A prominent example is eye tracking. DDMs can be applied to attention tasks by adding a simple bias parameter, essentially biasing drift towards the option or information currently attended. Although this addition is conceptually simple, the fact that the drift rate changes every time attention moves means that standard closed form solutions cannot be used. Thus the main fitting approach has been to run many discrete simulations. Log likelihood is then calculated based upon the proportion of simulations that correctly predict the response and reaction time. However, this approach has significant drawbacks: the inherent stochasticity in predictions means it cannot be used with automated minimisation functions such as Nelder-Mead, and it introduces a number of seemingly arbitrary variables into the fitting procedure.

We show that two of these variables are not arbitrary: the number of simulations conducted, and the degree of specificity in defining a correct reaction time prediction (generally defined as bin width, e.g. 500ms, 1s, quartiles). Simulations show that these variables interact to change the resulting model fits, and can greatly exacerbate the impact of stochasticity. We outline an alternative estimation technique which relies upon evolving probability density using a discrete approximation rather than upon discrete simulations that are updated at each time step. This eliminates issues of simulation numbers, and dramatically ameliorates issues of bin width selection. In addition, it eliminates stochasticity from estimates, meaning it can be used with automated minimisation algorithms.

Analytical Cognitive Modeling as a Linchpin between Levels of Functional Neuroimaging: The Case of

23/07 18:00
The Slate

Richard James Neufeld, Reggie Taylor, Colleen Cutler, Jean Theberge, Maria Densmore, Peter Williamson

Western University, Canada

Contemporary forms of functional neuroimaging include vascular, Blood-Oxygen-Dependent (BOLD) MRI (fMRI), Magnet Resonance Spectroscopy (fMRS), electromagnetoencephalography (MEG), and Evoked response Potential (ERP). Although differing in spatial and temporal resolution of neuroimaging signals, the alternate forms of neuroimaging can yield complementing information about cognition-related neuro-activation and neuro-connectivity (co-activation). A point of contact for the alternate forms of neuroimaging is that of a common cognitive challenge. Ascertaining the stability of cognitive performance across different forms of neuroimaging, occasions of measurement, settings of measurement, etc., arguably demands valid analytical monitoring of the presumed MRI transcending cognition. To serve as a communalizing agent, invariance of the 'f' of fMRI, etc., across the levels of functional neuroimaging ideally should be quantitatively established. The described strategy is demonstrated in a functional cognitive neuroscience study of Stroop-Task performance in schizophrenia. Functional MRS (addressing ACC glutamatergic mechanisms) was undertaken among schizophrenia participants, and psychiatric and healthy controls, followed 1.5 hours later by an fMRI study (addressing neuro-circuitry, through BOLD-signal seed-voxel time-series covariance), all at 7.0 Tesla, and using the same Stroop paradigm throughout. Congruent and incongruent word-color conditions, were intermixed with color-only (naming the color of 5 x's), and word-only (reading of a color word written in white against a black background) – altogether an amalgam of typical clinical-science, and systems-factorial-technology Stroop paradigms. Parametric and non-parametric stochastic modeling of latency distributions indicated consistency of model architecture and parameterized schizophrenia abnormalities. Potential limitations, mainly with respect to model mimicry, and paradigmatic constraints, are discussed.

Numerical Solution of Some Strongly Nonlinear Partial Differential Equations

23/07 18:00
The Slate

Morufu Oyedunsi Olayiwola

Osun State University, Osogbo, Nigeria, Nigeria

In this paper, a Variational Iteration Method (VIM) for the solution of some strongly nonlinear partial differential equations is presented. The results are in good agreement with the existing results in the literature.

23/07 18:00
The Slate

Diffusion model analysis: a graphical user interface with fast-dm

Stefan Tomov Radev, Veronika Lerche, Ulf Mertens, Andreas Voss
Institute of Psychology, Heidelberg University

Ten years ago, Voss and Voss (2007) introduced fast-dm, a free command-line tool for diffusion model data analysis. The program enables estimation of all parameters of Ratcliff's (1978) diffusion model from the empirical response time distributions of any binary decision task. The current development of fast-dm introduces an open-source graphical user interface (GUI) with the program. The GUI eliminates the necessity of writing error-prone control files and greatly facilitates the user-friendliness and flexibility of the program. It also incorporates additional functionality, e.g., a plotting tool for creating publication-ready plots. The utility of the new software will be demonstrated on exemplary data sets.

23/07 18:00
The Slate

Learning how students learn in a knowledge space theory based intelligent tutoring system

Egidio Robusto, Debora de Chiusole, Luca Stefanutti, Pasquale Anselmi
University of Padua, Italy

The research was aimed at studying and modeling learning processes induced by intelligent tutoring system (ITS) navigation. An ITS is a computerized system that aims at providing immediate and customized instruction to learners, without intervention of a human teacher. The ITS considered here is called KnowLab, a web based ITS developed by the authors at the University of Padua (Italy). This system is based on principles, procedures and mathematical models developed within the framework of competence-based knowledge space theory. The architecture of KnowLab is based on two different modules: the assessment and the learning modules, which are strongly connected to one another. The learning module is built by the system on the basis of previous adaptive assessments. Thus, after an assessment session, the system is capable of planning a personalized learning path for each student, by using different typologies of didactic objects (e.g., videos, instructions, solved exercises). The course currently available on the system is 'Psychometrics', a typical university course of the School of Psychology. In order to test the system's effectiveness on learning, students attending the course were asked to use the system for one month, in particular on two different knowledge sub-domains: 'descriptive statistics' and 'probability theory'. While a student uses the platform, several navigation data are recorded. Based on how the student interacts with the system and switches between the assessment and learning modules, different students' profiles were found which are related to the effectiveness of learning.

Computational modeling of decision making performance on the Cambridge gambling task with applications to samples of drug users

23/07 18:00
The Slate

Ricardo J. Romeu-Kelly[1], Jerome Busemeyer[1], Woo-Young Ahn[2], Nathaniel Haines[2] and Jasmin Vassileva[3]

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Our goal is to have a working model of the Cambridge Gambling Task (CGT) built to tease out the details of the individual differences between clinical populations. We focus on the CGT since, to our knowledge, there is currently a dearth of models for the task. Our model follows the 2 stages of the individual trials in the task, wherein both a color choice and a betting choice must be made, and the primary focus is in probability appreciation - or, how accurately the participant judges the probabilities from the 'data' given to them during the task - risk aversion, and impulsivity. Probabilities for betting choices are based on the expected utilities of the bets, as well as a cost of time for each betting ratio (since a trial can last up to 25 seconds). We apply the model to data on performance on the task from control participants, heroin users, amphetamine users, and poly users. Our initial analyses indicate that there are differences in risk aversion among the groups, as is consistent with the literature, as well as in the impulsivity parameter. Surprisingly, we initially have observed that probability appreciation does not appear to differ among the groups. After proposing and testing competing models (including simplifications of our current expected utility model), we can map out the differences and assess how the model and the task differentiate among the groups. We can then propose suggestions for clinical applications.

Rethinking windows and pools: how might models grow domain appropriate local connectivity structures?

23/07 18:00
The Slate

James Warren Ryland

University of Texas at Dallas, United States of America

Humans integrate myriad sensory signals into high-level understandings of their environment. To aid integration from layer to layer of cortex, neurons only looks at small groups of neurons in a preceding layer of cortex (Hubel & Wiesel 1962, 1965). This study will call that group a neuron's receptive window. The structure of these windows greatly enhances the ability of the model to learn useful representations, when correctly chosen. Low-level cortical areas group inputs by relatively accessible methods. For example, V1 groups inputs into windows largely by gross retinal position. However, later sensory areas group by largely unknown methods that have proven difficult to study (Booth & Rolls, 1998, Pierce, 2015; Rust & Dicarlo, 2010). Further, the best pattern recognition models to-date for understanding dense sensory data (i.e. CNNs) operate on receptive window assumptions that only relate to the organization of the lowest levels of sensory cortex. This study proposes a novel

theory of how cortex learns receptive windows in a generic modality independent fashion called Local Connectivity by Correlation (LCC). Under this theory, members of receptive windows are determined by their temporal intercorrelation across time. This theory proposes that correlation is sufficient to generate ideal window structures using the concept of feature-space-topology. Further, this paper will share preliminary simulations that illustrate how LCC can create window structures like those found in low-level cortical areas and simulated cortical maps.

23/07 18:00
The Slate

Using Agent-Based Modeling for Exploration of the Influence of Working Memory Capacity in CPR Dilemmas

Nadia Said[1], Helen Fischer[1], Dorothee Amelung[1] and Christian Kirches[2]

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Our atmosphere, water or international fisheries can be conceptualized as common pool resources (CPR). For these environments, we identified the working memory capacity (WMC) as a key driver of individual extraction behavior in our previous work, showing that when a group interacted with a common resource, higher WMC participants were more likely to extract unsustainably high amounts, causing a premature breakdown of the resource.

Albeit these results are highly suggestive, they are necessarily correlational in nature. Therefore, we use a mathematical modeling approach - agent-based modeling (ABM) - in order to vary WMC in a controlled way for agents interacting with a CPR.

We use an already fully parameterized mathematical model of the ACT-R declarative memory module (Said et al. 2016) to represent the memory capacities and temporal dynamics of the learning behavior of agents. This allows us to vary different cognition parameters, among others W (working memory) and tau (retrieval threshold), that model characteristic traits of various agents.

In this contribution we present first steps towards merging an ABM approach with the ACT-R declarative memory module. We discuss challenges and show next steps towards the application of mathematical optimization methods in order to make quantitative statements about optimal parameter values for different scenarios. This will allow us to investigate the optimal level of WMC for sustainable resource use, and thus to clarify the fundamental question of whether a more limited human WMC might prove beneficial for common resource use.

Bayesian modeling of human activity data based on the gamma family of dynamic models

23/07 18:00
The Slate

Jiro Sakamoto[1,2], Takumi Nagai[1], Yoshihiko Kunisato[3], Kosuke Sawa[3] and Natsuko Takata[3]

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Psychological and medical studies of wearable devices for measuring human activity are increasing. Most of those studies focus on group-level mean differences in activity. Testing for mean differences is accompanied by loss of time-series information, so it is preferred to adopt dynamic model analysis. However, it is not always possible to assume normality in dynamic models of human activity. In this study, we propose a Bayesian gamma family dynamic model and adapt it to real activity data. This model estimates a successive activity state corresponding to a series of activity values. Moreover, it assumes (1) the activity state moves with Gaussian noise minute-by-minute, and (2) observed values are generated from gamma distribution (shape parameter k = 1) with the activity state as the expected value. All participants provided written informed consent prior to the survey. Eighteen undergraduates (8 males, Mage (SD) = 21.67 (1.63)) met the inclusion criteria. They wore an activity-monitoring device for three days (Motion Watch 8, CamNtech Ltd). Bayesian modeling and parameter estimation were executed with R (version 3.3.2) and Hamiltonian Monte Carlo (HMC) sampling package rstan (version2.10.1). We found that our model could describe the smooth transition of the daily activity state. The Gelman-Rubin test showed all chains and samplings were well mixed and converged. The visual posterior predictive checks showed that our model performed better than the normal dynamic model, especially in dealing with zero. The gamma family of dynamic models with a Bayesian paradigm will help explore new insights in medical and psychological studies.

Get out of Dodge NOW! The Influence of Losing on Leaving

23/07 18:00
The Slate

Matthew-Donald D. Sangster, Wayne Gray

Rensselaer Polytechnic Institute, United States of America

We employ data from 957,000 matches from 36,000 teams of the massively multiplayer online game, League of Legends to examine three factors that link team performance to team dissolution; namely, (a) Last Match Outcome (LMO), the outcome (win/loss) of the most recent match (LMO) (b) number of matches previous played (MPP), and (c) the event of receiving a team rating (TR). The first two are events which are easily observable by the team members. The team rating is calculated by the game company and initial TR is given to the players after their 5th match with a given team. The TR reflects a complex calculation performed by the game company that allows Elo-type comparisons between performance of any two teams. Using Bayesian inference we describe how these three factors contribute

to the likelihood of team dissolution in this complex domain. The functions across the first four games are very distinct from those of other games. Across games 1-4 the team dissolution rate begins low and goes lower until game 5, when the initial TR is received. At game 5 the dissolution rate spikes. Following that spike, perhaps unsurprisingly, teams are much more likely to disband following a loss than a win. However, the likelihood of disbanding after a loss decreases the more that a team has played together. These results challenge a common assumption of longitudinal studies that drop outs are random.

23/07 18:00
The Slate

Structure model of personal escapist tendency

Tatiana Savchenko, Galina Golovina, Oxana Olkina, Arsenii Bakanov
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This research was supported by the Russian Foundation for Basic Research via grant 16-06-01085.

The work is aimed to analyze the psychological contents of the escapism phenomenon, and to design a validpsychometric instrument to measure personal escapist tendency. Escapism can be defined as a form of personal activity and realizes as a submersion into alternative reality. Five basic components Interpersonal conflict, Avoidance strategy, Activity shift, Alternative reality, Submersion, and the conjoint indicator of escapist tendency have been preliminary differentiated in the structure of escapism. Based on the structure, the psychometric test assessing the personal escapist tendency has been developed.

Results of the pilot study show that the test has satisfactory psychometric indicators (correlations between scales, constrictive validity, and one-time reliability). In addition to that, a few theoretically predicted significant empirical correlations have been found between the conjoint indicator of the personal escapist tendency with indexes of subjective well-being, reflexivity types, motivation of avoidance and self-development.

By dint of structural equation modeling, five- and three-factor models of the personal escapist tendency have been designed. It has been found out that the best decision is a three-factor model 2df=8 = 37,7 CFI = 0,996 SRMR = 0,009 RMSEA = 0,07 including the initial Interpersonal conflict and Alternative reality factors, and the joint one combining Avoidance strategy, Activity shiftand Submersion components. Based on results of the pilot study, perspectives of improving the personal escapist tendency test using the proposed three-factor model have been scheduled.

A model-based cognitive neuroscience account of individual differences in cognitive abilities

23/07 18:00
The Slate

Anna-Lena Schubert[1], Michael D. Nunez[2] and Joachim Vandekerckhove[2]

[1] Heidelberg University, Heidelberg, Germany, [2] University of California, Irvine, CA, USA

Previous research has established a firm link between individual differences in the speed of information-processing and cognitive abilities. To further understand the neuro-cognitive processes underlying this association, we recorded electroencephalographic (EEG) recordings from 122 participants while they performed a variety of reaction time tasks. An event-related potential (ERP) analysis of each participant's EEG recordings revealed latency differences in ERP components associated with higher-order cognition that predicted individual differences in cognitive abilities. Because these ERP components - in particular the P3 - have been previously associated with the drift rate parameter of the drift diffusion model, and because individual differences in drift rates have been shown to predict individual differences in cognitive abilities, we tested the hypothesis that drift rates mediate the relationship between ERP latencies and cognitive abilities. For this purpose, we compared the performance of a direct regression model, in which ERP latencies predicted cognitive abilities, to a mediation model, in which the effect of ERP latencies on cognitive abilities was mediated by drift rates. We obtained two main results: First, we replicated the association between ERP components reflecting higher-order processing and drift rates on a latent level. Second, we found no evidence that drift rates mediated the relationship between ERP latencies and cognitive abilities. Our results suggest that ERP latencies provide a purer measurement of the speed of higher-order cognition than behavioral data, possibly because behavioral data may be contaminated by cognitive processes unrelated to individual differences in cognitive abilities.

Effects of cognitive load on category learning

23/07 18:00
The Slate

Osung Seo, Michael Kalish

Syracuse University, United States of America

In the study, the differential effects of cognitive load on mechanisms of category learning are examined. The experiment was an extension of Kruschke's (1996) category-switch experimental paradigm with an additional cognitive load task.

The participants of the study were asked to learn the categories of eight freight trains that have three binary-valued dimensions (height, door, wheel). The categories of the trains in the pre-switch blocks depended on an XOR on two of the binary-valued dimensions. After learning the initial category structure, the participants learned one of the four post-switch category structures: reversal, relevant, irrelevant and compound shift. While learning the categories of the trains, the participants were also asked to do a simple cognitive load task.

The performance in the post-switch blocks of this experiment decreased compared to Kruschke's result. The performances in relevant, irrelevant and compound

shifts decreased dramatically. However, the performance in reversal shift decreased only to a slight degree. The model AMBRY (Kruschke, 1996) was fitted to the data, and the result suggests that category and attention learning were lowered by the additional cognitive load. State Trace Analysis and Bayesian Hierarchical Modeling were used to analyze and describe the results of the study.

23/07 18:00
The Slate

Successive mediocrity leads to steady, sure defeat: How novice Tetris players fail to manage their task environment

Catherine Laura Sibert, Wayne Gray

Rensselaer Polytechnic Institute, United States of America

Expertise is generally measured on a large scale: athletes winning competitions, surgeons executing complex procedures, or the final score in an action game. But each of these successes are made up of countless smaller steps leading to the end result, and understanding how novices and experts handle each step can provide insight into how the end result is achieved. In the action game Tetris, expert players accumulate high scores by making good choices about where to put each successive piece. Previous work found that simple AI models were capable of playing Tetris well, and by training the models under certain conditions, the models exhibited behavior similar to that of humans. In this work, we used the models to judge the goodness of each choice made by a player through a game. We traced how the range of best to worst possible moves - the task environment - changed throughout a game for novice and expert players. Novice play shows a steady decline of the task environment, while experts maintain a stable task environment until the very end stages of the game. The judgements of the models can also be used to identify possible errors in a game, allowing for an analysis of the frequency and type of errors made by players of different skill levels, as well as how players do or do not recover from mistakes.

23/07 18:00
The Slate

Understanding category specific semantic deficits using a network mathematical tool

Kaoutar Skiker, Mounir Maouene

Abdelmalek Essaadi's University, Tangier, Morocco, Morocco

http://www.ai.rug.nl/~mkvanvugt/ICCMprogram_files/paper_16.pdf

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Do depressive symptoms influence randomness in decision making in the reversal learning task? A hierarchical Bayesian modeling approach

23/07 18:00
The Slate

Keita Somatori[1,2] and Yoshihiko Kunisato[3]

[1] Graduate school of literature, Senshu University, [2] Research Fellow of Japan Society for the Promotion of Science, [3] Department of Psychology, School of Human Sciences, Senshu University

Depressive symptoms influence the exploration-exploitation balance in reinforcement learning. People with mild depression (PMD) make more exploratory decisions in a probabilistic choice task, in which the feedback that participants receive is constant. However, feedback is rarely constant in the real world. From a clinical perspective, it is important to understand how PMD behave in a changing environment. Therefore, we examined whether depressive symptoms influence the exploration-exploitation balance in a reversal learning task. In previous study, a summary statistics approach with a non-hierarchical model were applied. However, a Bayesian approach will enable us to make stable estimations and to hypothesize higher-ordered parameters in the model. Therefore, we applied a hierarchical Bayesian approach to analyze our data. Sixty-six undergraduates responded to the Patient Health Questionnaire-9, and engaged in a reversal learning task. In the task, participants were required to choose any one option from the two presented options and to learn which stimuli were associated with reward. When participants provided correct responses constantly, the correct stimuli were reversed. To estimate learning parameters, we used a standard Q-learning model. This model contains a learning rate parameter () and an inverse temperature parameter (variability of choice;). We found that depressive symptoms were negatively correlated with variability of choice, but they were not associated with learning rate. This result indicates that people with mild depression can update the value of each stimulus but not act based on the value. It may be impossible for PMD to exploit the value learned in a changing environment.

A Rational Approach to Stereotype Use

23/07 18:00
The Slate

Jake Spicer, Adam Sanborn

University of Warwick, United Kingdom

Existing theories of stereotype change have often made use of categorization principles in order to provide qualitative explanations for both the revision and maintenance of stereotypical beliefs. The present research examines the quantitative methods underlying these explanations, contrasting both rational and heuristic models simulating existing descriptions of stereotype change. These contrasts suggested differing predictions regarding reactions to high volumes of counter-stereotypical data, with the heuristic models expecting more sudden and drastic change at high volumes than the rational model. This was examined in an experiment in which measures of stereotypical beliefs were taken at multiple points throughout exposure to a large volume of predominantly counter-stereotypical information. Both empirical data

and model fits best corresponded with the predictions of the rational model, suggesting that stereotypes are in fact updated using rational categorization processes. This presents stereotype use as a more rational behavior than may commonly be assumed, and provides new avenues of encouraging stereotype change according to rational principles.

Building a polytomous knowledge structure: a data-driven methodology

23/07 18:00
The Slate

Andrea Spoto, Debora de Chiusole, Luca Stefanutti
University of Padua, Italy

In real applications of knowledge space theory (KST), one of the most important features is the knowledge structure construction. To date, several theory- and data-driven procedures are available for this aim. An example of the former is the cognitive task analysis, whereas examples of the latter are experts QUERY, (inductive) item tree analysis, D-SMEP and k-states. One of the core assumptions of KST is that the answer of a subject to an item is dichotomous (correct or incorrect). Extending KST to the case in which items are polytomous, the problem of having available a procedure for building structures is renewed. In the present research, a data-driven procedure for building polytomous structures was developed. It is based on an extension of the k-medians algorithm, in a similar way as k-states is based on an extension of the k-modes algorithm. This type of algorithms are used in computer science for solving clustering problems in many types of applications, such as unsupervised learning, classification and data mining. In particular, k-medians attempts to minimize the Manhattan distances between a set of observed points and its centroid. This minimization of distances is obtained by letting the centroid of each cluster to be the median of all points in that cluster. By using the KST terminology, the points in a cluster are the response patterns, whereas the centroid of the cluster is the state generating those response patterns. The algorithm is presented and the results of a number of simulation studies are discussed.

Identifiability of probabilistic knowledge structures and outcome preserving transformation groups

23/07 18:00
The Slate

Andrea Spoto, Luca Stefanutti
University of Padua, Italy

The basic local independence model (BLIM) is a probabilistic model, widely applied in knowledge space theory. It has recently received attention concerning its identifiability. In particular, it was shown that the BLIM is not identifiable for forward-graded (FG) and backward-graded (BG) knowledge structures, such as quasi-ordinal and learning spaces. This talk seeks to study the issue of BLIM's identifiability by examining groups of parameter transformations that, for FG and BG structures, keep constant the model's prediction function, thus making it unidentifiable. This

transformational approach is compared to the standard way of testing the local identifiability of a model, and its benefits are discussed. More specifically it is shown how this approach allow for simplifying the task of determining parameter transformations compared to the method via the null space of the Jacobian matrix. Moreover, it is shown that the transformational approach allows for studying particular cases to which the traditional approach does not apply, namely those in which parameters assume the value 0. Finally, it is shown that the approach can be generalized to knowledge structures that are neither FG nor BG.

It is new, but will it be good? Context-driven exploration of novel options

23/07 18:00
The Slate

Hrvoje Stojic, Eric Schulz, Maarten Speekenbrink

University College London, United Kingdom

How do people decide whether to try out novel options? We argue that they infer novel options' rewards from contextual information and learned functional relations. We propose a Bayesian optimization model to describe their learning and decision making. The model relies on similarity-based learning of functional relationships between features and rewards, and a choice rule that balances exploration and exploitation through the relative uncertainty of predictions. The model makes two predictions. First, decision makers who learn functional relationships will generalize based on the reward function, choosing novel options only if its predicted reward is high. Second, they will take uncertainty about the function into account, and prefer novel options that can reduce this uncertainty. In two preregistered experiments, we examine participants' preferences for novel options using a feature-based multi-armed bandit task in which rewards are a noisy function of observable features. Consistent with the first prediction, we show that participants preferably choose a novel option if its features indicate high rewards, but shun the option if its features indicate low rewards. With regards to the second prediction, we find some evidence that participants prefer novel options when they are less similar to previously experienced options. We conclude that contextual learning is a parsimonious yet powerful explanation of behavior in the face of novelty.

23/07 18:00
The Slate

The Irrationality of Political Prediction Market Prices

Ryan Stokes, Mac Strelioff
University of California at Irvine, United States of America

Prediction markets are a relatively new tool for forecasting the outcomes of paramount events such as political elections or movements in financial markets. Participants in prediction markets buy or sell contracts with payoffs that depend on the occurrence of a future event. The price of these contracts is determined by the market of buyers and sellers. Rational decision theory asserts that, if the participants are rational agents, then the market price of a contract should equate to the probability of the underlying event. Indeed, prior research has found that forecasts based on prediction markets can outperform forecasts based on economic models or polling data. However, individual probabilistic reasoning often violates assumptions of rationality, which may undercut the accuracy of predictions based on these markets. Using publicly available data from PredictIt, a political prediction market, we found biases in prediction market prices that are consistent with established biases in individual probability judgements. Specifically, we find that market price generally overestimates the likelihood of low probability events and underestimates the likelihood of high probability events. Here we investigate the source of this bias in light of research on individual biases in probabilistic reasoning and common gambling biases. Implications for the accuracy of forecasts based on prediction market data are discussed.

23/07 18:00
The Slate

Structure learning for action-modified schedules of reinforcement

Mac Strelioff, Mimi Liljeholm
University of California, Irvine, United States of America

A fundamental distinction in learning theory is between interval and ratio schedules. Whereas on interval schedules a response is rewarded based on the amount of time elapsed since the last reward, on ratio schedules, a response is rewarded based on the number of responses since the last reward. These qualitatively distinct schedules produce different response profiles, with interval schedules generating much lower levels of responding. The interval schedule can be conceptualized as a case in which the rate of performing an action modifies the schedule of reinforcement, rather than just the rate of reward: Specifically, on a given interval schedule, any response rate greater than one per the required interval will decrease the probability of reward given the action. Here, we present a Bayesian structure inference model that evaluates the ability of an action to modulate the probability of reward given that same action, or given some alternative action. Our findings apply to a wide range of real-world scenarios involving action-modified schedules of reinforcement, such as checking email, overfishing, or shifting gears to modify the influence of the gas pedal on acceleration.

Image Analysis of Psychological Projective Drawings by Patients with Schizophrenia

23/07 18:00
The Slate

Kazuhisa Takemura[1], Keita Kawasugi[1], Yumi Iwamitsu[2], Hitomi Sugawara[2], Sakura Nishizawa[3], Yasuyuki Tsukamoto[3], Asako Nobutou[3], Akiko Kodaira[3], Junichi Todoroki[3] and Keiko Toforoki[3]

[1] Waseda University, Japan, [2] Kitasato University, Japan, [3] Tsuruga Hospital, Japan

We proposed image analysis methods to address the lack of objectivity in interpreting drawings when projective drawing techniques were used. Although projective drawing techniques are traditional and relatively old methods in clinical psychology and psychiatry, they are still used frequently among clinical psychologists, psychiatrists, and pychotherapists. During the test, the respondent is presented with a blank piece of paper and standard instructions on what is to be drawn (house, tree, or person). Unlike the Rorschach inkblot test or thematic apperception test (TAT), the projective drawing test presents a maximum of ambiguity for the respondent.In the present study, we propose an interpretation method using discrete wavelet transform (DWT) and multiresolution analysis, and show examples of pictures drawn by patients with Schizophrenia. We also compare the results of discrete Fourier analysis and singular value decomposition method with discrete wavelet analysis.Participants were admitted to A Hospital and diagnosed with schizophrenia based on DSM-IV-TR. Written informed consent was obtained from each participant prior to initiation of this study. The participants were asked to draw a tree (Baum Test) and answer 2 questionnaires.The obtained drawings were scanned to create digital images. The resolution is 300dpi, format is tiff, the number of pixels of height and width are 3508 and 2480 respectively. In the multiresolution analysis, we used Haar wavelet of a computational program MATLAB. We interpreted their psychological process from the results of the image analysis.

Enabling fine-grained search through the modelling of subjectively perceived properties

23/07 18:00
The Slate

Christian Wagner[1,2], Josie McCulloch[1] and Shane Mueller[2]

[1] University of Nottingham, United Kingdom, [2] Michigan Technological University, USA

Reasoning about human preferences and choice is a well-established area of research interest, the outcomes of which are exceedingly relevant with the pervasive application of search algorithms to support the access of everything from information to consumer goods. Current, in particular user-adaptive search technologies such as employed my major online search engines are frequently criticised for their potential to result in user lock-in, i.e. the narrowing of the search and thus result space in response to perceived user preferences based on prior choices or the choices of peers.

We describe a knowledge-based recommendation system in which user preferences are elicited via preference ranges (rather than a single value), which are then used to form a multi-dimensional fuzzy-set model of preferences. An extension of traditional similarity and distance measures on fuzzy sets is then put forward to

enable the comprehensive reasoning on the resulting models in respect to user preferences.

We demonstrate the approach using a case-study in the context of personalised manufacturing, specifically, the production of personalised orange-flavoured drinks. Consumers can state their ideal product through queries (e.g. Juice like x but sweeter), resulting in tailored recommendations such as rankings of products which match the consumers' preferences.

Modelling Neural Correlates of mathematical diagrammatic reasoning

23/07 18:00
The Slate

Duo Wang, Mateja Jamnik, Pietro Lio
University of Cambridge, United Kingdom

Our project studies the neuro-correlates of mathematical diagrammatic reasoning. Human brain is good at transforming abstract concepts, like mathematical theorem and entity relationships, into diagrams which facilitate understanding and reasoning about such concepts. For example, researchers show that for syllogism-solving tasks, group using Euler diagram to facilitate problem-solving have on average lower brain activations measured with fMRI than that of the group without using diagrammatic aid, indicating that diagrammatic reasoning reduces the cognitive load. Our aim is to study the neural correlates of such diagrammatic reasoning for a wide range of mathematical problems. We believe results of this study can then be used to guide researches in machine automated reasoning to build more capable and human-like reasoning system. Artificial Neural Network (ANN) has be shown to correspond to human neural activities at a significant level. One particular type of ANN, Convolutional Neural Network (CNN), has been particularly successful recently in image processing and speech recognition tasks. Recent research discovered significant correlations between CNN and brain activations of human testers when both are processing the same visual input. However little research has been done on modelling the reasoning engine, the pre-frontal cortex(PFC). This project studies neural activities in PFC, in combination with other cortical areas, while people are undertaking diagrammatic reasoning, and develop mathematical models that correlate human neural activities to artificial neural systems. We combine Bayesian analysis, graph and community theory and artificial neural system for this purpose.

Detecting Macro Cognitive Influences in Micro Cognition: Using Micro Strategies to Evaluate the SGOMS Macro Architecture as implemented in ACT-R

23/07 18:00
The Slate

Robert West, Nathan Nagy, Fraydon Karimi, Kate Dudzik
Carleton University, Canada

http://www.ai.rug.nl/~mkvanvugt/ICCMprogram_files/paper_50.pdf

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Intensive longitudinal data analysis with Bayesian hierarchical Ornstein-Uhlenbeck model

23/07 18:00
The Slate

Wai Wong
University of Leuven, Belgium

Intensive longitudinal design involves sequential measurements and intervals between measurements are short (daily basis, or even hourly) and occasionally uneven. Due to short period of time between measurements, serial correlations are more prominent in such design than in traditional longitudinal design. Various approaches have been suggested for the analysis of longitudinal studies. Multilevel models constitute a popular class of models in this context, but other models have been suggested. Bayesian hierarchical Ornstein-Uhlenbeck model (BHOUM), which is derived from Ornstein-Uhlenbeck stochastic process, aims at modelling data with serial correlations and unequal time intervals between measurements - the very nature of intensive longitudinal data.

Previous researches (Oravecz & Tuerlinckx, 2011; Oravecz, Tuerlinckx & Vandekerckhove, 2016) in this fields have explored the practical application of the BHOUM in continuous outcome data and the comparison with traditional techniques such as multilevel models. We will discuss the background of BHOUM and extend its application in all common research setting by reconstructing the BHOUM framework so that it is applicable in both continuous and categorical outcomes, e.g. binary, ordinal, nominal response data, etc. In addition, comparison between the new BHOUM framework and traditional techniques such as multilevel models will be discussed.

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The effect of top-down control on the selection of decision strategies

23/07 18:00
The Slate

Cheng-Ta Yang, Jay Chen, Pei-Yi Lin
National Cheng Kung University, Taiwan

Top-down control plays an important role in the selection of an optimal perceptual decision strategy. However, in the previous studies, inferences about the strategies were primarily based on participants' subjective reports after they completed all the experiments, which cannot reflect their trial-by-trial strategies. Hence, this study investigated whether participants can be consciously aware of and control their strategies. A double-dot detection task was conducted and Systems Factorial Technology (SFT, Little et al., 2017; Townsend & Nozawa, 1995) was used for experimental design, data analysis, and inferences. In Experiment 1, participants were

asked to report their strategy (serial or parallel strategy) immediately after each trial; in Experiment 2, participants were asked to pre-select a strategy before a trial started. Results of Experiment 1 showed that all the participants adopted a parallel self-terminating or coactive processing strategy regardless of their reported strategies. Similarly, results of Experiment 2 showed that all the participants adopted a parallel self-terminating strategy regardless of their chosen strategies. These findings suggested that participants fail to intentionally adopt serial processing to detect redundant targets. These results occurred perhaps because pre-attentive processing is not affected by top-down control and our results can further the understandings of how top-down control affects the selection of decision strategies.

23/07 18:00
The Slate

Individual Differences in Gaze Dynamics in Risky Decision-making

Siyuan Yin, Jennifer Trueblood
Vanderbilt University, United States of America

In risky decision-making, cumulative prospect theory (CPT) is widely used to examine the cognitive processes involved in choice behavior. However, it is unknown how these cognitive processes relate to attention and information search. In this study, we explore the relationship between latent cognitive processes (as measured by CPT) and eye movement patterns (which serve as a proxy for attention and information search). Participants made choices between gambles presented perceptually as flickering grids in which three monetary values were indicated by colors and probabilities by color proportions. To explore attention and information search patterns, we investigated eye movement patterns when faced with different gambles in two experiments and correlated these patterns with the parameters of CPT. In one experiment, the three colors used were equally salient (pink, blue, and yellow). We observed that people who are more risk-seeking tend to look at risky options more often. We also found that choices are related to their last gaze. In the second experiment, only one value, either the maximal value (risk-salient) or the minimal value (safe-salient), was colored (red) with the other two values in different shades of grey. We found that people under risk-salient condition were more likely to choose risky options than people under safe-salient condition. People who are more risk-seeking examine non-salient options more carefully. In addition, choices were related to both the first and last items viewed in the risk-salient condition. These results bridge choice behavior conceptualized by CPT and attention and information search strategies revealed by eye movements.

Examining relationship between cocaine addiction and reward-related brain activity with regularized generalized CCA

23/07 18:00
The Slate

Ju-Chi Yu[1], Vincent Guillemot[2], Richard Briggs[3], Braud Jacquelyn[4], Adinoff Bryon[4,5], Gu Xiaosi[1] and Abdi Hervè[1]

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Neuroscience studies often involve multiple descriptions for the studied population. Regularized generalized canonical correlation analysis (RGCCA) is a component-based technique that studies the relationship between multiple blocks of variables that describe the same group of participants. RGCCA identifies the most relevant subsets of variables that maximize the correlation among all blocks. RGCCA integrates the flexibility of partial least square (PLS) path modeling with the more generalized framework of canonical correlation analysis. In addition, with multivariate approaches, RGCCA analyzes the pattern within each block, a feature which allows to associate neural activation pattern to events of interest and other information. However, no study has applied RGCCA to a data set that involves neural activation.

In this study, RGCCA is applied to the analysis of multiple sets of variables that describe 39 cocain-dependent participants, along with their behavioral and BOLD responses to a probabilistic reversal learning task. The study examines how reward-related brain activation and behaviors are associated with cocaine addiction. The five blocks involved are: (1) the demographic data, (2) the level of craving described by several questionnaires, (3) the level of cocaine usage, (4) the behavior data, and (5) reward-related BOLD signals in the task. RGCCA analyzes the pattern of neural activation with fMRI data and limits the false positive rate resulting from multiple comparisons in a standard general linear model (GLM) approach. In conclusion, RGCCA is a versatile method that makes it possible to associate brain activations with path assumptions between more than two sets of variables.

Fechner & Mathematics: The history of a close relationship

23/07 18:00
The Slate

Verena Zudini

University of Trieste, Italy

The poster focuses on the fundamental role played in Fechnerian psychophysics by mathematics. It enabled Fechner to pursue his aim of carrying out the experimental measurement of sensations and founding psychophysics as a quantitative science.

This aim was clear from the very definition of psychophysics as an exact science. Since, according to Fechner, any exact doctrine had to begin with the measurement of its objects, it was necessary to show how psychophysics allowed the measurement of psychical magnitudes.

According to Fechner's thought, if we cannot measure sensations directly, nevertheless we can measure the stimuli that provoke them and determine the thresholds of sensations, especially the differential ones, using them as the unit of measurement; we have to measure sensations through the measure of the stimuli that induce equally noticeable sensations, finding a method for determining the equality of two given sensations.

Fechner used the results on differential sensitivity obtained by Weber some years before, according to which equal relative increments in the stimulus corresponded to equal increments in the sensation. He generalized them and formulated what he called 'Weber's law.'

Starting from Weber's law, Fechner took what he considered to be an experimental result, i.e. the fact that the just noticeable difference in sensation was constant, and applied calculus to sensation conceived as a phenomenon which increased in time and was susceptible to infinitesimal variations. Therefore he enunciated his logarithmic 'measurement formula'.

This measurement formula, called today 'Fechner's law', is considered the first explicit, quantitative formulation connecting sensations with stimuli.

24/07 09:00
The Slate

Context-driven effects in perception and cognition: a variational approach

Edoardo Provenzi[2] and Giorgio Gronchi[1]

[1] University of Florence, Italy, [2] Universite Paris Descartes, France

Starting from a computational analysis of the Rudd-Zemach model of achromatic induction, we describe a variational framework that can be extended to context-driven effects in cognition. The key ingredient of the framework is an optimal balance between dispersion (a positive correlation bias between judgement and context) and contrast (a negative correlation bias between judgement and context). We advocate that this balance lies at the basis of contextual effects within perception and also cognition.To show the validity of the proposed variational framework, we describe several examples of such functionals in the field of color perception and social cognition, where empirical observations are in line with theoretical predictions. Moreover, we present novel data supporting our variational framework. The simultaneous presence of contrast intensification and dispersion control is coherent with the idea of a concurrent presence of both effects in each judgment hypothesized by some social cognition theories. In general, the proposed variational framework can represent an innovative view from above on perceptual and cognitive phenomena and it is able to produce new constraints and predictions.

Analysis of a Common Neural Component for Finger Gnosis and Magnitude Comparison

24/07 09:00
Tiered
Scarman

Terrence C Stewart[1] and Marcie Penner-Wilger[2]

[1] University of Waterloo, Canada, [2] King's University College at Western University

We recently developed a spiking neuron model that performs magnitude comparison and finger gnosis tasks using a common underlying neural system, explaining why performance on these tasks is associated in humans. Here, we explore the parameters in the model that may vary across individuals, generating predictions of error patterns across the two tasks. Furthermore, we also examine the neural representation of numbers in the magnitude comparison task. Surprisingly, we find that the model fits human performance only when the neural representations for each number are not related to each other. That is, the representation for TWO is no more similar to THREE than it is to NINE.

"Is this a Dax I see before me?": the effects of sample selection and sample size on generalization and categorization

24/07 09:00
Space 41
Scarman

Keith Ransom[1], Andrew Hendrickson[2], Amy Perfors[1] and Daniel J. Navarro[3]

[1] University of Adelaide, Australia, [2] Tilburg University, Netherlands, [3] University of New South Wales, Australia

Categorization and generalization are fundamentally related inference problems. Yet leading computational models of categorization (as exemplified by, e.g., Nosofsky, 1986) and generalization (as exemplified by, e.g., Tenenbaum & Griffiths, 2001) make qualitatively different predictions about how inference should change as a function of the number of items observed. Holding all else equal, categorization models predict that increasing the number of examples observed in a category increases the chance of assigning a new item to that category; generalization models predict a decrease, or a tightening with additional exemplars (this is known as the size principle). We discuss the results of a series of experiments which investigate the effect of increasing sample size in comparable categorization and generalization tasks. We find evidence in favour of category expansion in categorization tasks (in line with exemplar-based models of categorization), yet find evidence in favour of tightening inference in generalization tasks (in line with generalization models). We further find that these apparent reversals depend upon the manner in which examples are thought to have been selected. When participants were encouraged to believe that examples were selected at random, then a difference in base rate leads to expansion of the more frequent category. In contrast, when people were encouraged to believe that additional examples were provided by a helpful teacher, categorization reflected generalization - in both cases additional examples led to tighter inferences.

24/07 09:00
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Scarman

Improving Decision Field Theory for Consumer Choice Modelling Applications

Thomas O. Hancock, Stephane Hess, Charisma F. Choudhury
Choice Modelling Centre, Leeds University, United Kingdom

In previous researches, Decision Field Theory (DFT) has predominantly been used to explain context effects such as similarity, attraction and compromise effects. However, the requirement of computationally intensive simulations has impeded use of the model in consumer choice modelling applications. One noticeable exception is Berkowitsch et al. (2014), who avoided simulation by applying a simplification allowing the calculation of probabilities of alternatives after preferences stabilised. In this paper, we propose a theoretical improvement for the mechanism behind DFT which allows probabilities of alternatives to be calculated at any moment in time whilst simultaneously avoiding computationally intensive simulation. As well as providing DFT with much greater flexibility, this improvement allows it to become more competitive with models traditionally used in choice modelling. We find that DFT provides a better fit than both Multinomial Logit and Random Regret Minimisation as well as alternative dynamic choice models such as the Multi-attribute Linear Ballistic Accumulator, for both estimating and forecasting travel mode choices. Additionally, this improvement allows us to incorporate a decision-makers' response time into a DFT model, which also improves model fit. Finally, we demonstrate several approaches for incorporating heterogeneity, both across and within decision-makers, within a DFT model. Results indicate that random parameters for addressing the heterogeneity vastly improve the model fit. The paper is expected to serve as an important step in bridging the gap between mathematical psychology and consumer choice modelling.

24/07 09:20
The Slate

Modeling Word Learning through Context

Hyungwook Yim[1], Vladimir Sloutsky[2], Xin Yao[3] and Simon Dennis[1]
[1] The University of Newcastle, Australia, [2] The Ohio State University, [3] Unilever Corporation

Studies and computational models of word learning have mostly focused on ostension (i.e., explicit naming of a visually present referent or candidate referents) as a mechanism to map a word to its meaning. However, not all words could be learned through ostension either because they are abstract and have no referent, or because the referents are not present when the word is uttered. We propose an associative account that explains word learning through context and how the pattern of learning changes through development. The model is implemented as a neural network model that learns two types of associations (i.e., syntagmatic associations and paradigmatic associations) from a natural corpus. A syntagmatic association refers to the association among words that co-occur in an utterance such as furry and dog as in 'the furry dog'. A paradigmatic association refers to words that have a similar context such as dog and cat as in 'the furry dog' and 'the furry cat'. The

paradigmatic associations are second order associations and could be built up on the basis of the syntagmatic associations, and therefore would come online after the syntagmatic associations. We argue that this delay in learning the paradigmatic associations could explain the developmental changes in word learning. The model is supported by 16 experiments across two age groups, and naturally explains the developmental pattern as a function of experience.

Parameter exploration of a neural model of state transition probabilities in model-based reinforcement learning

24/07 09:20
Tiered
Scarman

Mariah Martin Shein, Terrence C Stewart, Chris Eliasmith
University of Waterloo, Canada

We explore the effects of parameters in our model of model-based reinforcement learning. In this model, spiking neurons are used to represent state-action pairs, learn state transition probabilities, and compute the resulting Q-values needed for action selection. All other aspects of model-based reinforcement learning are computed normally, without neurons. While some of these parameters have expected effects, such as increasing the learning rate and the number of neurons, we find that the model is surprisingly sensitive to variations in the distribution of neural tuning curves and the length of the time interval between state transitions.

Uncovering Unsupervised Categorization Biases using Markov chain Monte Carlo with People

24/07 09:20
Space 41
Scarman

Joseph L Austerweil, Nolan Conaway
University of Wisconsin - Madison, United States of America

A central debate in the categorization literature concerns how people expect category members to be distributed across a domain. In a continuous domain, leading prototype, exemplar, and hybrid (clustering) models assume that categories are represented by one or more Gaussian distributions (corresponding to the category prototype, all observations, or some middle-ground, respectively). While much of the debate has focused on supervised categorization, recent work by Pothos and colleagues (2011) evaluated categorization models on their ability to explain human unsupervised categorization of 'bug' stimuli that vary on two continuous dimensions. Their work is an important first step, but is limited: It only provides comparisons for a subset (nine arrangements of 16 items) of an arbitrarily large number of possible conditions. Rather than evaluate participant expectations over a series of experimenter-defined arrangements, we used Markov chain Monte Carlo with People (MCMCP) to efficiently and accurately elicit expectations about what the arrangements ought to be. In our study, participants observed 15 bug-stimuli and generated the 16th; over many such iterations, the participant's biases are uncovered. Each participant completed nine chains, initialized to the conditions tested by Pothos et al. We found support for greater levels of abstraction: participants tended to group

category members into a single prototypical group, or a small number of clusters (described by one Gaussian distribution, or a mixture of a small number of Gaussians). We evaluate prominent categorization models according to these results and discuss their implications.

Using Eye Trajectories to Understand Preference Formation of Risky Choices

24/07 09:20
Space 43
Scarman

Moshe Glickman, Orian Sharoni, Dino Levy, Marius Usher
Tel-Aviv University, Israel

Risky choice is subject to a number of violations of normative decision-making, which are accounted by several descriptive models, such as the Expected Utility (EU) and the Cumulative Prospect Theory (CPT). These models, however, are not process models. In this study, we examine the time-course of risky choices (lotteries), by tracking the eye-trajectories of the participants, who choose between two lotteries (win x with a probability p). The behavioral results indicate risk aversion, which appears to increase with the lottery-amount (x), and we find that eye-trajectories predict the choice beyond what is predicted by purely economic models (EU). We fit the data via a number of traditional descriptive models (EU, CPT), as well as a novel process model, which is constrained by eye-trajectories. In this process model, the preferences are integrated from the representations of the amounts and of the probabilities, with the current attended attribute (amount or probability) receiving a higher weight. The model shows a better data fit (AIC/BIC measures) then the descriptive choice models, it accounts for the choices and their RT, and allows us to understand the role of attention in generating preferences and in making decisions. In particular, the model allows us to examine individual differences in the decision process, based on the eye-tracking trajectories (within or between alternatives).

The importance of word order in the distributional construction of meaning

24/07 09:40
The Slate

Melody Dye, Michael Jones, Daniel Yarlett, Michael Ramscar
Indiana University, United States of America

Distributional models of semantics formalize the notion that the meaning of a given word is a function of the contexts in which it occurs. In line with this, prior research has established that a word's semantic representation can be manipulated - pushed toward a target meaning, for example - by situating that word in distributional contexts frequented by the target. Left open to question is the role that sequential order plays in the distributional construction of meaning. Learning occurs in time, and it can produce asymmetric representations depending on the order in which information is presented: differences in representation which parallel those seen between discriminative and generative classifiers in machine learning. While this phenomenon has been well-documented in domains like categorization, where

subjects learn about the predictive relationships between words and the world, it has received comparatively little attention in distributional learning, where subjects learn about the predictive relationships among words themselves. Discriminative learning models predict that systematically manipulating a word's preceding context should more strongly influence its meaning than should varying what follows. In this talk, I will review the empirical results that lend support to this hypothesis, and discuss the implications for cross-linguistic analyses and modeling.

Basal Ganglia-Inspired Functional Constraints Improve the Robustness of Q-value Estimates in Model-Free Reinforcement Learning

24/07 09:40
Tiered
Scarman

Patrick Rice, Andrea Stocco
University of Washington, United States of America

Due to the correspondence between the striatal dopamine signal and prediction error signal utilized by model-free reinforcement learning methods, computational psychological research has found much success in modeling the basal ganglia as a biological implementation of a reinforcement learning mechanism. A large majority of these modeling efforts have focused on applying the tenets of reinforcement learning to the proposed functions of the basal ganglia, but few (if any) have attempted to apply crucial aspects of basal ganglia neurophysiology to reinforcement learning mechanisms. Here, we propose a basal ganglia-plausible model that explicitly utilizes two symmetric sets of actions (analogous to the basal ganglia's direct and indirect pathways), to simultaneously update value estimates of both available actions (i.e. chosen and not chosen) in the Probabilistic Stimulus Selection (PSS) task. We demonstrate that this proposed model architecture outperforms a standard reinforcement learning model of the PSS task by eliminating the standard model's bias towards estimation of the most valuable available actions, while granting improved resistance to noise in the internal selection process.

IBL-Bayes: A Bayesian Implementation of the Instance-Based Learning model of choice

24/07 9:40
Space 41
Scarman

Jeffrey Stephen Chrabaszcz[1], Emmanouil Konstantinidis[2] and Cleotilde Gonzalez[1]
[1] Carnegie Mellon University, United States of America, [2] University of New South Wales, Australia

Instance-based learning (IBL) theory describes two mechanisms that constrain decisions under risk made from experienced, as opposed to described, information: memories decay over time (controlled by the decay, d, parameter) and subjective probabilities are partially stochastic (controlled by the noise, s, parameter). Originally developed in ACT-R, IBL parameters are routinely estimated using grid search. Past modeling with IBL often fit the free parameters in IBL (d and s), at the aggregate level, ignoring both individual differences and parameter uncertainty, despite

the availability of highly structured datasets that would allow researchers to estimate parameters corresponding to these additional features. We propose a new Bayesian implementation of the IBL model of choice which allows for individual differences in IBL parameters and for multilevel structure by participant across multiple decision environments. To demonstrate the advantages of IBL-Bayes, we present a comparison between previous analysis of an experiment including both within and between-subject factors and a reanalysis using IBL-Bayes. In this experiment, people were assigned to make decisions from experience in a series of six decision environments either alone or in a group. In each decision environment, the person or group repeatedly made consequential choices between two risky options, one stationary and one non-stationary (i.e., dynamic). IBL-Bayes includes multilevel structure to partially pool parameter estimates across repeated measurements by participant and additional modifications that assume stochastic choice. This new analysis serves both to expand inferences from this existing dataset and to serve as a model for future application of IBL models.

Challenges in estimating loss aversion using accept-reject tasks

24/07 09:40
Space 43
Scarman

Lukasz Walasek, Neil Stewart
University of Warwick, United Kingdom

Decision makers are loss averse—they tend to overweight losses relative to gains. Loss aversion is often measured in the accept-reject task, in which participants are asked to decide whether they would accept or reject the chance of playing each of a series of mixed gambles (50/50 two-branch gambles with varying gain and loss amounts). Researchers use prospect theory to quantify this overestimation in the lambda parameter. Here, we use simulations to show that this method suffers from severely poor parameter recoverability. Even in a very simple version of prospect theory, with linear probability weighting and value functions (except for the loss aversion kink at zero), lambda cannot be reliably estimated, even if participants were subjected to thousands of experimental trials. We show that these issues are driven by the trade-off between lambda and the bias parameter included in the stochastic choice rule. However, a measure derived from these parameters is extremely well recovered—and corresponds to estimating the area of gain-loss space in which people accept gambles. This area is equivalent to the number of gambles accepted in a given choice set. That is, simply counting accept decisions is extremely reliably recovered—but using prospect theory to make further use of exactly which gambles were accepted and which were rejected simply does not reveal a recoverable lambda.

Connectionnist language models as models of human language expectations: Learning Simpler Language Models with the Delta Recurrent Neural Network Framework

24/07 10:00
The Slate

David Reitter, Alexander Ororbia

The Pennsylvania State University, United States of America

Learning useful information across long time lags is a critical and difficult problem for temporal neural models in tasks like language modeling, and it is one that humans excel at compared to artificial neural networks. While human cognition can re-train and learn many different tasks, neural networks show catastrophic forgetting. The idea of lifelong learning proposes a framework that supports continuous learning from a stream of data, semi-supervised learning (from labeled and unlabeled examples), and robustness in face of a changing environment.

Here, we examine whether short-term and long-term memory elements, inspired but not directly modeled after human psychology, can improve model performance in language modeling.The Delta Recurrent Neural Network (Delta-RNN) framework is a simple and high-performing design that unifies previously proposed gated neural models.

The Delta-RNN models maintain longer-term memory by learning to interpolate between a fast-changing data-driven representation and a slowly changing, implicitly stable state. This requires hardly any more parameters than a classical simple recurrent network, much unlike state-of-the-art systems that are unrealistically large. The models outperform popular complex architectures, such as the Long Short Term Memory (LSTM) and the Gated Recurrent Unit (GRU) and achieve state-of-the art performance in language modeling at character and word levels and yield comparable performance at the subword level.

Toward a Neural-Symbolic Sigma: Introducing Neural Network Learning

24/07 10:00
Tiered
Scarman

Paul Simon Rosenbloom[1], Abram Demski[1] and Volkan Ustun[2]

[1] University of Southern California, United States of America, [2] USC Institute for Creative Technologies

Building on earlier work extending Sigma's mixed (symbols + probabilities) graphical band to inference in feedforward neural networks, two forms of neural network learning - target propagation and backpropagation - are introduced, bringing Sigma closer to a full neural-symbolic architecture. Adapting Sigma's reinforcement learning (RL) capability to use backpropagation then yields a form of neural RL that is still combinable with probabilistic action modeling.

24/07 10:00
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Scarman

A Poisson random walk model for response times in multi-alternative categorization

Steven P. Blurton, Sren Kyllingsbk, Claus Bundesen
Department of Psychology, University of Copenhagen, Denmark

Based on a simple 'what first comes to mind' rule, the Theory of Visual Attention (TVA; Bundesen, 1990, Psych Rev) provides a general and well interpretable account of visual attention in tasks such as partial and whole report of well discriminable stimuli. Here we propose a TVA-based model of visual identification of confusable stimuli in speeded response time (RT) tasks. We assume that tentative classifications are made during the identification of a stimulus and that these can be modeled by Poisson generators. Visual identification is made conclusively in favor of one alternative once the number of tentative categorizations favoring this categorization exceeds the number favoring the other categories by a critical amount (the response threshold). In the special case of a categorization task with only two alternatives, evidence accumulation follows a simple random walk with exponentially distributed interstep times. This framework is mathematically well tractable and allows for analytic solutions of interesting generalizations, such as trial-to-trial variation in the Poisson processing rates. However, the model can be further generalized to account for RT distributions in multi-alternative categorization. This generalization is based on the assumption of competitive accumulators that retain properties of random walk models but are not restricted to two alternatives (Usher & McClelland, 2001, Psych Rev). We fitted the model to RT distributions of both binary and multi-alternative categorization. The model provides a good description of RT data across all conditions and inherits favorable properties of the TVA, such as well interpretable parameters of the visual identification process.

24/07 10:00
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Scarman

Psychological parameters have units: A bug fix for stochastic prospect theory and other decision models

Neil Stewart[1], Benjamin Scheibehenne[2] and Thorsten Pachur[3]
[1] University of Warwick, United Kingdom, [2] Geneva School of Economics and Management, University of Geneva, [3] Center for Adaptive Rationality, Max Planck Institute for Human Development

To fit models like prospect theory or expected utility theory to choice data, a stochastic model is needed to turn differences in values into choice probabilities. In these models, the parameter measuring risk aversion is strongly correlated with the parameter measuring the sensitivity to differences in value. We use dimensional analysis from the physical sciences to show that this is because the sensitivity parameter has units which depend on the risk aversion parameter. This means that comparing sensitivities across individuals with different level of risk aversion is meaningless and forbidden. We suggest a simple bug fix for prospect theory and other decision models which corrects this problem, and demonstrate that the bug fix completely removes the correlation between sensitivity and risk aversion parameters in model

estimations and allows parameters to be interpreted as they were originally intended.

Concepts, control and context: A connectionist account of normal and disordered semantic cognition

24/07 10:40
The Slate

Paul Hoffman
University of Edinburgh, United Kingdom

Semantic cognition requires a store of conceptual representations shaped by verbal and non-verbal experience, as well as executive control processes that ensure that this knowledge is activated in a way that meets current task demands. I will present a connectionist computational model of semantics that aims to meet both of these challenges. The model has a hybrid structure that integrates the view, from cognitive neuroscience, that concepts are grounded in sensory-motor representation with the view, from computational linguistics, that knowledge is shaped by patterns of lexical co-occurrence. Importantly, executive influences on semantics are included in the form of a controlled retrieval mechanism that provides top-down input to amplify weak semantic relationships. I will demonstrate how the model represents abstract and concrete words, associative and taxonomic relationships, and the multiple meanings of homonyms, within a single representational space; and how damage to the representational and control elements of the model can simulate impairments seen in neuropsychological patients with loss of semantic representation vs. control processes respectively.

A causal role for right frontopolar cortex in directed, but not random, exploration

24/07 10:40
Tiered
Scarman

Wojciech Zajkowski[1], Malgorzata Kossut[2] and Robert Wilson[3]
[1] SWPS University, Poland, [2] University of Social Sciences and Humanities, Warsaw, [3] University of Arizona

The explore-exploit dilemma occurs anytime we must choose between exploring unknown options for information and exploiting known resources for reward. Previous work suggests that people use two different strategies to solve the explore-exploit dilemma: directed exploration, driven by information seeking, and random exploration, driven by decision noise. Here, we show that these two strategies rely on different neural systems. Using transcranial magnetic stimulation to inhibit the right frontopolar cortex, we were able to selectively inhibit directed exploration while leaving random exploration intact. This suggests a causal role for right frontopolar cortex in directed, but not random, exploration and that directed and random exploration rely on (at least partially) dissociable neural systems.

Computing Bayes factors via thermodynamic integration with an application using the Linear Ballistic Accumulator model

24/07 10:40
Space 41
Scarman

Brent Miller, Jeff Annis, Nathan Evans, Thomas Palmeri
Vanderbilt University, United States of America

The computation of the Bayes factors, necessary for Bayesian model selection, involves computing the marginal likelihood for each model and taking the ratio. The marginal likelihood is obtained by integrating over the entire parameter space, making the estimation of the Bayes factor for models with more than a few dimensions problematic for methods like quadrature. Early Monte Carlo methods such as arithmetic/harmonic mean estimators or reversible-jump MCMC have been used with some success, but still face problems (Friel & Wyse, 2012). Other solutions exist, such as processing on GPUs (Evans & Brown, in press), but are challenging to implement and are done on a model-by-model basis. We will briefly review Monte Carlo techniques to compute marginal likelihoods and present a recent advancement called thermodynamic integration (Friel & Pettitt, 2008; Lartillot & Philippe, 2006). The method is extremely general, and can be easily implemented in existing MCMC code. We validate the method by comparing marginal likelihoods obtained for the Linear Ballistic Accumulator to the findings in Evans & Brown.

Selective Information Sampling and the In-Group Heterogeneity Effect

24/07 10:40
Space 43
Scarman

Elizaveta Konovalova, Gael Le Mens
Universitat Pompeu Fabra, Spain

People often perceive their in-groups as more heterogeneous than their out-groups. We propose an information sampling explanation for this in-group heterogeneity effect. Using computer simulations, we analyze a model in which an agent forms beliefs and attitudes about social groups from her experience. Consistent with robust evidence from the social sciences, we assume that people are more likely to interact again with in-group members than with out-group members. This implies that people obtain larger samples of information about in-groups than about out-groups. Because estimators of variability tend to be right-skewed, but less so as sample size is large, sampled in-group variability will tend to be higher than sampled out-group variability. This implies that even agents that process information correctly – even if they are naive intuitive statisticians – will be subject to the in-group heterogeneity effect. Our sampling mechanism complement existing explanations for the in-group heterogeneity effect that relied on how information about in-group and out-group members is processed.

Integrating conceptual and syntactic information to understand the development of English verb classes

24/07 11:00
The Slate

Lisa Pearl

UC Irvine, United States of America

The process of language acquisition draws on a variety of information sources, including conceptual and syntactic cues. I discuss the integration of these cues in a probabilistic model of children's development of English verb classes, which allow children to recognize which linguistic contexts a verb can be used in. I evaluate existing representational theories that synthesize conceptual and syntactic cues in different ways by embedding these theories in a computational model of the language acquisition process. Current findings suggest an intuitive developmental trajectory for conceptual and syntactic representations, matching children's observed verb class knowledge from three to five years old.

A Neural Accumulator Model of Antisaccade Performance of Healthy Controls and Obsessive-Compulsive Disorder Patients

24/07 11:00
Tiered
Scarman

Vassilis Cutsuridis

University of Lincoln, United Kingdom

Antisaccade performance in obsessive-compulsive disorder (OCD) is related to a dysfunctional network of brain structures including the (pre)frontal and posterior parietal cortices, basal ganglia, and superior colliculus. Previously recorded antisaccade performance of healthy and OCD subjects is re-analyzed to show greater variability in mean latency and variance of corrected antisaccades as well as in shape of antisaccade and corrected antisaccade latency distributions and increased error rates of OCD patients relative to healthy participants. Then a well-established neural accumulator model of antisaccade performance is employed to uncover the mechanisms giving rise to these observed OCD deficits. The model shows: i) increased variability in latency distributions of OCD patients is due to a more noisy accumulation of information by both correct and erroneous decision signals; (ii) OCD patients are almost as confident about their decisions as healthy controls; ii) competition via local lateral inhibition between the correct and erroneous decision processes, and not a third top-down STOP signal of the erroneous response, accounts for both the antisaccade performance of healthy controls and OCD patients.

Warp-III Sampling for Comparing Complex Cognitive Models

24/07 11:00
Space 41
Scarman

Quentin F. Gronau, Dora Matzke, Eric-Jan Wagenmakers
University of Amsterdam, Netherlands, The

Mathematical psychologists are regularly faced with the statistical challenge of comparing two or more possibly non-nested models. The principled Bayesian solution to this problem is to compute posterior model probabilities and Bayes factors. Both quantities rely on the marginal likelihood of the models which is in many applications a high-dimensional integral that cannot be evaluated (completely) analytically. Computing the marginal likelihood is especially challenging in the hierarchical framework which may be the reason why thus far, principled Bayesian model comparisons have only been conducted for a limited set of hierarchical cognitive models. Here we discuss warp-III sampling (Meng & Schilling, 2002), a general method for accurately computing the marginal likelihood of hierarchical cognitive models. Warp-III sampling is an advanced version of bridge sampling that enables the efficient estimation of the marginal likelihood even for cases in which the posterior distribution is non-normal. We demonstrate the practical feasibility of the method in the context of hierarchical cognitive models, discuss advantages and disadvantages of the procedure, and allude to possible improvements.

Scientific facts versus the public's rational rejection of evidence

24/07 11:00
Space 43
Scarman

Stephan Lewandowsky[1] and Gordon Brown[2]
[1] University of Bristol and University of Western Australia, [2] University of Warwick, United Kingdom

Some well-established scientific findings may be rejected by notable segments of the population. Although some of the individual-level variables that determine people's stance towards scientific evidence are well understood, less is known about how such information spreads through society and how people's opinions are shaped by those of others. We present an agent-based simulation of how people sample and then express attitudes in light of social norms and consumption of news media. The model assumes that agents located within a social network observe the behavior of neighbours and infer from their behavior the social distribution of particular attitudes (e.g. towards climate change). Agents are assumed to dislike behaviours that are extreme within their neighbourhood (social extremeness aversion), and hence have a tendency to conform. However, agents are also assumed to prefer choices that are consistent with their own true beliefs (authenticity preference). Expression of attitudes reflects a compromise between these opposing principles. We apply the model to a number of public-opinion trends relating to acceptance of the scientific evidence about climate change. The model sheds light on a variety of variables, including the importance of the perceived rather than actual scientific consensus, "balanced" media coverage, and the polarizing effect of those variables on attitudes to climate change.

Predicting item-level effects of relatedness with models based on prediction and counting

24/07 11:20
The Slate

Pawel Mandera[1], Emmanuel Keuleers[2] and Marc Brysbaert[1]

[1] Ghent University, [2] Tilburg University, Netherlands

Recently, a new class of distributional semantic models has been proposed (Mikolov et al., 2013) that can be trained on a text corpus and allows to measure semantic similarity between words. In contrast to more traditional models accomplishing similar goals, such as HAL and LSA, the new class of models can be trained iteratively by learning to predict co-occurring words without an explicit representation of the full co-occurrence pattern. We discuss the relevance of the new class of models for psycholinguistic theories and compare them to more traditional models based on a set of tasks involving semantic processing: large dataset of semantic priming (Hutchison et al., 2013), human associations, TOEFL, relatedness and similarity ratings. We conclude that all investigated types of models allow to predict item-level effects of semantic relatedness in behavioral tasks, but the prediction-based models usually offer a better fit to human data. Theoretically, we argue that these models bridge the gap between traditional approaches to distributional semantics and psychologically plausible learning principles. As an aid to researchers, we release pre-computed semantic vectors for English and Dutch for a range of models together with a convenient interface that can be used to extract a great number of semantic similarity measures.

A Neurocomputational Model of Learning to Select Actions

24/07 11:20
Tiered
Scarman

Andrea Caso, Richard P Cooper

Birkbeck University of London, United Kingdom

We present an extension of a schema-based architecture for action selection, where competition between schemas is resolved using a variation of a neuroanatomically detailed model of the basal ganglia. The extended model implements distinct learning mechanisms for cortical schemas and for units within the basal ganglia. We demonstrate the functionality of the proposed mechanisms by applying the model to two classic neuropsychological tasks, the Wisconsin Card Sorting Task (WCST) and the Probabilistic Reversal Learning Task (PRLT). We discuss how the model captures existing behavioural data in neurologically healthy subjects and PD patients and how to overcome its shortcomings.

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Scarman

A Weak Harmonic Transitivity Axiom

G Charles-Cadogan
University of Leicester, United Kingdom

We introduce a weak harmonic transitivity (WHT) axiom that is (1) dual to the weak stochastic transitivity axiom, and (2) robust to mental accounting for joint receipts of binary choice and their associated mental states. WHT axiomatizes an abstract harmonic probability weighting function (HPWF) that mimics random fields driven by mental states. The HPWF accommodates 'anchor adjustment' of probabilistic risk attitudes. Theory predicts that the structure function, i.e., variogram, of the mental states component of HPWF fluctuates over the distribution of outcomes in a lottery. To apply the theory, we specify a HPWF, calibrate it to popular inverse S-shape pwf, and show how to estimate it with harmonic regression. We show how heteroskedasticity correction serves double duty as a debiasing factor for recovering linear probabilities from distorted probabilities.

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The evolution of optimal and heuristic strategies for sequential sampling

Peter Kvam, Arend Hintze
Michigan State University, United States of America

Theories of decision strategies often propose optimal or heuristic approaches to a task based on their performance and computational demands. Explicitly or implicitly, researchers assume that the cognitive mechanisms required to implement these strategies are learned or evolved. But what does evolution have to say about what strategies should or should not have developed? In this talk, we present a method of studying the evolutionary process by using biologically-inspired artificial Markov brain agents that must make decisions. Using performance on a standard reward rate maximization task to determine agents' fitness, we show how generations of selection, mutation, and reproduction lead to the development of diverging decision strategies under different task conditions. Both the quality of decision information and the relative magnitude of punishments and rewards (for incorrect or correct decisions) affect evolved strategies: high-quality information and light punishments lead to optimal evidence accumulation approaches, while low-quality information and harsh punishments lead to ones resembling heuristics. This is primarily due to the memory demands that the task imposes - high thresholds for decision certainty require greater information capacities, and lower stimulus information quality means that longer strings of information must typically be stored before a decision can be reached. In these cases, heuristics like run rules can circumvent memory demands by dropping information along the way, sacrificing decision time to maintain decision accuracy. We discuss potential implications for human decision behavior, including the plausibility of optimal strategies and the neural circuitry required to implement heuristics and evidence accumulation models.

A two-stage model of the development of semantic categories

24/07 11:40
The Slate

Jon Willits, Philip Huebner
UC Riverside, United States of America

What is semantic categorization? In this work, we explore on old answer to this question: Categorization is a hybrid two distinct processes. The first process involves unsupervised learning of relations between objects, providing a representation of objects that is useful for a wide range of possible goals (one of which is categorization). The second process involves supervised category learning, explicitly learning to put objects into categories. Critically, this second process uses the representations of the first process as its starting point, dramatically simplifying the process of category learning. Here, we demonstrate this process using a two-stage neural network model. The first stage is a recurrent neural network model, which learns to predict word sequences in a corpus of child-directed speech. This model is not explicitly trained to learn semantic categories. Nonetheless, we show that it learns highly-structured and useful semantic structures. Its representations, while not yet ideal for categorization, are nonetheless are well-suited as input for the second stage of the model. The second stage model is then explicitly trained to perform semantic categorization (e.g. that dog and cat are both mammals, and shoe and sock are both clothing), and achieves 100% accuracy on this task when using the representations provided by the first stage recurrent neural network. However, it fails to learn the categories when using random representations or random category assignments. We believe this model demonstrates that a task- or goal-oriented perspective of semantic cognition has promise for furthering our understanding of semantic processing.

Gaps Between Human and Artificial Mathematics

24/07 11:40
Tiered
Scarman

Aaron Sloman
University of Birmingham, UK, United Kingdom

The Turing-inspired Meta-morphogenesis project begun in 2011 was partly motivated by deep gaps in our understanding of mathematical cognition and other aspects of human and non-human intelligence and our inability to model them. The project attempts to identify previously unnoticed evolutionary transitions in biological information processing related to gaps in our current understanding of cognition. Analysis of such transitions may also shed light on gaps in current AI. This is very different from attempts to study human mathematical cognition directly, e.g. via observation, experiment, neural imaging, etc. Fashionable ideas about "embodied cognition", "enactivism", and "situated cognition", focus on shallow products of evolution, ignoring pressures to evolve increasingly em disembodied forms of cognition to meet increasingly complex and varied challenges produced by articulated physical forms, multiple sensory capabilities, geographical and temporal spread of important information and other resources, and "other-related meta-cognition" concerning mental states, processes and capabilities of other individuals. Computers

are normally thought of as good at mathematics: they perform logical, arithmetical and statistical calculations and manipulate formulas, at enormous speeds, but still lack abilities in humans and other animals to perceive and understand geometrical and topological possibilities and constraints that (a) are required for perception and use of affordances, and (b) play roles in mathematical, and proto-mathematical, discoveries made by ancient mathematicians, human toddlers and other intelligent animals. Neurally inspired, statistics-based (e.g."deep learning") models cannot explain recognition and understanding of mathematical em necessity or em impossibility. A partial (neo-Kantian) analysis of types of evolved biological information processing capability still missing from our models may inspire new kinds of research helping to fill the gaps. Had Turing lived long enough to develop his ideas on morphogenesis, he might have done this.

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Scarman

A Quantum Theory Account of Order Effects and Conjunction Fallacies in Political Judgments

James Yearsley, Jennifer Trueblood
Vanderbilt University, United States of America

Are our everyday judgments about the world around us normative? Despite decades of research in the judgment and decision-making literature suggesting otherwise, there has been a recent resurgence in normative theories of human judgment. In this talk I will describe a large (N=1200) experiment conducted during the US Presidential primaries examining two classic judgment phenomena: order effects and conjunction fallacies. The data display strong evidence for both phenomena, the co-occurrence of which cannot be explained by existing normative theories. I will show that the results are consistent with quantum probability theory, in particular I will explain two a priori and parameter free critical tests that can be derived in quantum theory, and which are obeyed by the data. Finally I will discuss two factors that appear to moderate the effects, cognitive thinking style as measured by the Cognitive Reflection Test and political ideology.

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The wisdom of select cues

Shenghua Luan, Daniel Barkoczi
Max Planck Institute for Human Development, Germany

In their seminal study on the efficacies of different weighting-and-adding models, Dawes and Corrigan (1974) concluded that: 'The whole trick is to decide what variables to look at and then to know how to add.' Since then, the 'how to add' part has generated much interest in psychological research, whereas little has been done or known on 'what variables to look at' in the first place. In out-of-sample prediction with limited learning samples, our analytical work shows that adding more predictor variables or cues can cause both benefit and harm for prediction accuracy, resulting in a single-peaked function between the number of cues considered and accuracy, and

this function holds regardless of whether cues are weighted equally or differentially. We then tested these theoretical predictions in a simulation study involving 39 real-world data sets. The results show that for both paired-comparison and quantity estimation tasks, the highest accuracy was achieved when not all but a few selected cues were used. The exact number of cues leading to the peak accuracy depends on the weighting scheme (i.e., equal or differential), the size of the learning sample, and the cue selection method. We also conducted an 'ecological rationality' analysis, identifying the key environmental properties affecting the performance of strategies with select cues. Our study connects well with recent research on the wisdom of select crowds in group decision making. It also provides intuitive explanations on why algorithms with built-in feature selection mechanisms, such as lasso regression, often outperform ordinary methods in prediction.

Toward a Cognitive Modeling Rosetta Stone

24/07 13:10
The Slate

Joseph Woodworth Houpt
Wright State University, United States of America

Computational cognitive architectures and mathematical cognitive models each have their own research communities and each approach has its own strengths. In light of the increasing connections between ICCM and SMP communities, I will be discussing recent work connecting ACT-R with probabilistic formalisms including Markov chains. While ACT-R is formal model of cognition that makes specific, quantitative predictions, it is less amenable to modern model assessment approaches and is not directly comparable to analytic models. Additionally, analytic methods are often more efficient, which facilitates real-time application. As an example of this work, I will present an analytic representation of a recently published ACT-R model of the effect of fatigue on sustained attention. I will end by discussing this project in the context of a broader goal of leveraging the complementary advantages of computation cognitive architectures and mathematical modeling.

Not every credible interval is credible: Evaluating robustness in the presence of contamination in Bayesian data analysis

24/07 14:40
The Slate

Lauren Kennedy[1], Daniel J. Navarro[2], Amy Perfors[1] and Nancy Briggs[3]
[1] University of Adelaide, Australia, [2] University of New South Wales, Australia, [3] Mark Wainwright Analytical Center, University of New South Wales

As Bayesian methods become more popular among behavioral scientists, they will inevitably be applied in situations that violate the assumptions underpinning typical models used to guide statistical inference. With this in mind, it is important to know something about how robust Bayesian methods are to the violation of those assumptions. In this paper we focus on the problem of contaminated data (such as data with outliers or conflicts present), with specific application to the problem of

estimating a credible interval for the population mean. We evaluate five Bayesian methods for constructing a credible interval, using toy examples to illustrate the qualitative behaviour of different approaches in the presence of contaminants, and an extensive simulation study to quantify the robustness of each method. We find that the 'default' normal model used in most Bayesian data analyses is not robust, and that approaches based on the Bayesian bootstrap are only robust in limited circumstances. A simple parametric model based on Tukey's 'contaminated normal model' and a model based on the t-distribution were markedly more robust. However, the contaminated normal model had the added benefit of estimating which data points were discounted as outliers and which were not.

24/07 14:40
Tiered
Scarman

Noisy Reasoning: a Model of Probability Estimation and Inferential Judgment

Fintan Costello[1] and Paul Watts[2]

[1] UCD, Ireland, [2] Dept. of Theoretical Physics, NUI Maynooth

We describe a computational model of two central aspects of people's probabilistic reasoning: descriptive probability estimation and inferential probability judgment. This model assumes that people's reasoning follows standard frequentist probability theory, but is subject to random noise. This random noise has a regressive effect in probability estimation, moving probability estimates away from normative probabilities and towards the center of the probability scale. This regressive effect explains various reliable and systematic biases seen in people's probability estimation. This random noise has an anti-regressive effect in inferential judgment, however. This model predicts that these contrary effects will tend to cancel out in tasks that involve both descriptive probability estimation and inferential probability judgment, leading to unbiased responses in those tasks. We test this model by applying it to one such task, described by Gallistel et al. (2014). Participants' median responses in this task were unbiased, agreeing with normative probability theory over the full range of responses. Our model captures the pattern of unbiased responses in this task, while simultaneously explaining systematic biases away from normatively correct probabilities seen in other tasks.

Low Dimensional Representations in Multi-Cue Judgement

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Joyce Wenjia Zhao[1], Sudeep Bhatia[1] and Clintin Davis-Stober[2]

[1] Department of Psychology, University of Pennsylvania, Philadelphia, PA, [2] Department of Psychological Sciences, University of Missouri, Columbia, MO

The study of multi-cue judgement investigates how decision makers integrate cues to predict the value of a criterion variable. We consider a multi-cue judgment task in which decision makers have prior knowledge of inter-cue relationships but are ignorant of how the cues correlate with the criterion. We assume that decision makers use a priori weighting schemes to evaluate the cues. A naive judgment strategy prescribes an equal weight for each cue, whereas an optimal weighting scheme uses the eigenvector corresponding to the largest eigenvalue of the inter-cue correlation matrix.

Across three lab experiments, we find that the optimal weighting scheme provides a good description of participants' behavior. On the aggregate level, this model outperforms all other weighting scheme models, except for the equal weights model (which has nearly identical fits). On the individual level, a substantial subgroup of participants are better described by the optimal model relative to the equal weights model. In addition, the optimal model successfully predicts the use of lexicographic strategies.

Our results suggest that decision makers may represent cues in a low-dimensional space, with a projection that can be approximated by a principle components analysis on the inter-cue correlation matrix. The use of such a representation is consistent with core insights in semantic memory research and has important optimality properties concerning judgment accuracy.

Modeling cognitive abilities in considering effects due to item-position and processing speed

24/07 14:40
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Scarman

Karl Schweizer

Goethe University Frankfurt, Germany

Although measures of cognitive abilities are considered as very homogeneous, they frequently show effects unrelated to the ability of interest that is to be represented. Possible effects that are likely to impair the modeling of the ability of interest are the item-position and speed effects. The item-position effect denotes the influence of the responses to earlier items on the responses to later items. It is obvious in changes of the response probability and variance. The speed effect is an effect that is likely to be observed when there is speeded testing since participants usually differ according to the number of items which they reach and attempt during a given time span.

The modeling of abilities using confirmatory factor models is frequently impaired by such effects, and it may happen that the model is rejected because of impairment due to the effects instead of a faulty representation of the ability. In order to overcome this problem, the representation of the ability and also of effects by constrained factor loadings is proposed and investigated.

The empirical work included the collection of data by means of one speeded scale and one non-speeded scale. Furthermore, there was also a non-speeded scale including items arranged according to a quasi-random sequence. In the data obtained by both non-speeded scales a model including representations of ability and item-position effect was sufficient for achieving a good model fit. In contrast, in speeded data additionally the representation of the speed effect is necessary.

24/07 15:00
The Slate

Some Theoretical Issues Regarding the use of Bayes Factors for Cognitive Models

Simon Segert, Sanghyuk Park, Clintin Davis-Stober
University of Missouri, United States of America

Bayes factors are a powerful tool for carrying out statistical model selection. We consider issues that may arise when using Bayes factors to differentiate among models where there is no unique 'zero knowledge' prior distribution. Specifically, we contrast differences between non-informative priors defined over the parameters of a model versus non-informative priors over the total predictive space of a model. We illustrate this through a worked example of the selective integration model of Tsetsos et. al. (2016). This problem, although common in Bayesian methods, is especially acute when, as in this model, the parameters are not directly measurable, and are novel quantities which the experimenter has no prior knowledge about (and thus no a priori reason to favor one distribution over another). We discuss possible solutions to specifying such priors.

24/07 15:00
Tiered
Scarman

Cognitive Computational Models for Conditional Reasoning

Marco Ragni[1] and Alice Ping Ping Tse[2]
[1] University Freiburg, Germany, [2] The University of Granada

Premises in conditional reasoning consist of an "if" statement (e.g., "if I can catch the bus, I won't be late") and a fact (e.g., I can catch the bus). Such types of simple inference have been studied empirically and formally for about a century. In the past five decades, several cognitive theories have been proposed to explain why humans deviate from predictions of conditional logic. In this article, we (i) describe existing theories, (ii) develop multinomial processing tree (MPT) models for these theories and systematically extend the theories with guessing subtrees to test the predictive power of cognitive models. The models are evaluated with G2, Akaike's (AIC) and Bayesian Information Criteria (BIC), and Fisher's Information Approximation (FIA). Mental model theory with directionality for indicative conditionals while the independence model for counterfactuals provide the best fits to data from psychological studies.

Object Representation in Multiattribute Choice

24/07 15:00
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Scarman

Sudeep Bhatia[1] and Neil Stewart[2]

[1] University of Pennsylvania, United States of America, [2] University of Warwick, United Kingdom

We outline a theoretical framework for understanding how everyday choice objects are represented and how decisions involving these objects are made. Our framework combines insights regarding object and concept representation in semantic memory research with multiattribute choice rules proposed by scholars of decision making. We also propose computational techniques for using our framework to quantitatively predict naturalistic multiattribute choices. We test our approach in two-object and three-object forced choice experiments involving common books, movies, and foods. Despite using complex naturalistic stimuli, we find that our approach achieves high predictive accuracy rates, and is also able to provide a good account of decision time distributions.

Using cognitive modelling to better understand the heritability of cognition.

24/07 15:00
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Scarman

Nathan Evans[1], Mark Steyvers[2] and Scott Brown[3]

[1] Vanderbilt University, [2] University of California, Irvine, [3] University of Newcastle, Australia

An enduring topic of research interest relates to the heritability of mental traits, such as intelligence. Some of the work on this topic has focussed on genetic contributions to the speed of cognitive processing, by examination of response times in psychometric tests. An important limitation of previous work is the underlying assumption that variability in response times solely reflects variability in the speed of cognitive processing. This assumption has been problematic in other domains, due to the confounding effects of caution and motor execution speed on observed response times. We extend a cognitive model of decision-making to account for the relatedness structure in a twin study paradigm. This approach has the potential to separately quantify different contributions to the heritability of response time: contributions from cognitive processing speed, caution, and motor execution speed. Using data from the Human Connectome Project, we find that caution is both highly heritable and highly influenced by the environment, while cognitive processing speed is moderately heritable with little environmental influence, and motor execution speed appears to have no strong influence from either. Our study suggests that the assumption made in previous studies of the heritability being within mental processing speed is incorrect, with response caution actually being the most heritable part of the decision process.

24/07 15:20
The Slate

Using data augmentation to enable nonparametric Bayesian hypothesis testing

Johnny Boy van Doorn, Maarten Marsman, Eric-Jan Wagenmakers
University of Amsterdam, Netherlands, The

An often recurring question in psychological and cognitive science is whether its constructs ought to be treated on the ordinal level, or ratio/interval level. Examples of such data are Likert scales, preference rankings, or test performance scores. Having statistical analyses more closely related to the measurement level of the data diminishes the risk of erroneous assumptions, and better approximates the psychological processes underlying the observed data. In viewing rank data as the ordinal manifestations of a latent, normally distributed variable, the actual construct that psychologists strive to measure is more accurately quantified in terms of uncertainty. Through the use of Gibbs sampling to augment ordinal data, posterior distributions for the latent scores and the test statistic can be obtained. We present this framework to conduct nonparametric Bayesian hypothesis tests of association (Kendall's tau) and difference of means (Wilcoxon's rank sum and signed rank statistics).

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Tiered
Scarman

Beyond the Visual Impedance Effect

Alice Ping Ping Tse[1], Marco Ragni[2] and Johanna Lösch[2]
[1] The University of Granada, [2] University Freiburg, Germany

Whether the mental representation of reasoning problems is spatial or visual (or mixed) in nature has been the subject of considerable debate for years. The visual impedance effect found in Knauff & Johnson-Laird (2002) has provided us with new insights into this question. The study found that the forming of excessive visual images induced by the premises can impede relational reasoning. This study aimed at investigating the factor of complexity on the visual impedance effect in two folds, namely number of term series (i.e., total number of premises plus the conclusion) and whether the entities in the premises are presented in a continuous manner (i.e., whether the subject of the argument is the same as the object of the previous argument). In line with previous studies, relational category, number of term series and successiveness were the main factors of the response time. Results of the parameter estimation by generalized estimating equation showed that visual relations, 5-term series and discontinuous problems were the only significant parameters. The results again suggested that irrelevant visual images can hinder reasoning processes, in addition to the complexity of the problem. We proposed a combined cognitive model of ACT-R and PRISM for the findings in this study.

Modelling moment to moment attention bias in multi attribute choice

24/07 15:20
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Scarman

Timothy L Mullett[1] and Richard J Tunney[2]

[1] University of Warwick, United Kingdom, [2] University of Nottingham, United Kingdom

When deciding between two alternatives, individuals must shift their attention between the choice options, but also between different attributes, or pieces of information. For example, when selecting the more valuable flat to rent, the number of bedrooms and the number of bathrooms cannot be presented in the same visual space, and therefore must be attended separately. Individuals' attention patterns often appear chaotic, with attention shifting rapidly and often revisiting information that has already been examined. However, reliable patterns have been identified. One is the late onset bias, or gaze cascade: the finding that in the moments immediately preceding a response, attention becomes increasingly biased towards the item that is subsequently chosen.

Using a novel millisecond-by-millisecond analysis technique we show that in multi-attribute choice, attention becomes increasingly biased towards the attribute that best differentiates the options. However, the differentiation must be weighted both by the values on the individual trial, and also by the weight that a subject gives to each attribute as implied by their behavioural responses. This performs significantly better than alternative hypotheses, including attention being biased towards the attribute with the largest total. The time-course of this attribute-wise bias is quite different to that of the item-wise bias. The attribute bias develops earlier, though still time-locked to the moment of response. It then disappears as the item-wise bias develops and is at chance when a response is given. These patterns are robust across a variety of multi-attribute tasks including apartment choice, health choice, and gamble choice.

Preference shifts or more errors: How increased cognitive load changes decision making

24/07 15:20
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Scarman

Jörg Rieskamp[1], Sebastian Olschewsiki[1] and Benjamin Scheibehenne[2]

[1] University of Basel, Switzerland, [2] University of Geneva, Switzerland

How do people make preferential choices in situations where their cognitive capacities are limited? In the literature, many studies link the manipulation of cognitive resources to qualitative changes in preferences. However, there is a widely overlooked alternative hypothesis: Namely that a reduction of cognitive capacities leads to an increase in choice error and hence less reliable preferences. We developed a mathematical model and a hierarchical Bayesian estimation to test to what extent a reduction in cognitive capacities leads to a shift in preferences or an increase in choice error. Using a within-subject n-back task to manipulate cognitive load, we conducted three experiments across different choice domains, including risky choice, temporal discounting, and strategic interaction (ultimatum game). Across all three domains results show that a reduction in cognitive capacity credibly affected

participants' level of choice error rather than their respective preferences. These results hold on an individual and on a group level. In sum, our approach and the mathematical model we used provides, contrary to past work, a rigorous test of how reduced cognitive capacity affects people's decision making behavior.

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The Slate

A Bayesian approach for the Wilcoxon signed-rank statistic

Richard A. Chechile
Tuft University, United States of America

A Bayesian analysis is provided for the Wilcoxon signed-ranks statistic. The Bayesian analysis is based on a parameter on the (0,1) interval that is the population parameter which generated the observed signed-ranks value. For the case of a uniform prior probability distribution for the parameter and for small sample sizes, values for the statistic are computed that enable probabilistic statements. For larger sample sizes, the asymptotic distribution for is provided. Power analyses are examined both for properly specified Gaussian models as well as for misspecified nonGaussian models. The new Bayesian metric had a high power efficiency in the range of 0.9 to 1 relative to a standard t test for the Gaussian cases, but if the sampling was from an unknown and misspecified distribution, then the new statistic can have a considerably higher probability for detecting a difference between conditions relative to the parametric test. This method is thus a particularly useful and robust method for applications when the usual parametric assumptions are questionable. These properties further enable a way to do a generic Bayesian analysis for many nonGaussian distributions that currently lack a formal Bayesian model.

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Tiered
Scarman

Implementing Mental Model Updating in ACT-R

Sabine Prezenski
TU Berlin, Germany

This paper demonstrates how mental models and updates of mental models due to system changes can be modeled with the cognitive architecture ACT-R using explicit mechanisms. The mental model building and updating is modeled with a representation chunk and a control chunk. The representation chunk holds the strategy, the expected outcome and an evaluation mechanism of the strategy. The control chunk holds information over environmental conditions and the learning history. This modeling approach was developed and tested for smartphone application tasks and then implemented in a dynamic decision making task investigating strategy development with complex stimuli. The later task used different multi-feature auditory stimuli material. The modeling approach explained data of participants in the smartphone studies very well and met the trends found in the dynamic decision making task.

A unidimensional representation of value drives preferences for most- and least-favored options

24/07 15:40
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Scarman

Guy Hawkins[1], Towhidul Islam[2] and Anthony Marley[3,4]

[1] University of Newcastle, Australia, [2] University of Guelph, Canada, [3] University of Victoria, Canada, [4] University of South Australia, Australia

Preferential choice has traditionally been studied in paradigms where people indicate their most-preferred option from a set of options. More recently, this 'pick the best' paradigm has been extended to one where people indicate their most- and least-preferred options, known as best-worst scaling. Best-worst scaling has been motivated on grounds of efficiency because it elicits more information regarding preferences from each trial than the conventional approach. This motivation only holds, however, if the preference-related information driving 'worst' choices is systematically related to the information driving 'best' choices; the validity of the latter has been debated in the applied choice literature. Here, we tested the hypothesis that a unidimensional representation of value underlies best and worst choices. In five large-scale data sets across domains ranging from toothpaste preferences to spending in the Government Budget, we tested three models of best-worst choice: two that assumed the representation of value underlying best and worst choices is related, and a third that assumed independent representations. Using Bayesian latent mixture modeling that allows model selection at the group and individual-participant levels, we found strong evidence across all data sets that the value representation driving best choices is systematically related to the value representation driving worst choices. These in-sample model selection results were further supported with out-of-sample predictive tests using longitudinal choice data from three of the data sets. We conclude that a unidimensional - not multidimensional - representation of value is the likely driver of preferences for most- and least-preferred options.

Metric Based CCT

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Scarman

Gregory E Alexander

University of California, Irvine, United States of America

The goal is to construct a general continuous model of CCT for distance data. Cultural consensus theory (CCT) is an information pooling technique that utilizes natural differences that arise amongst informants to construct a culturally viable answer key to questions with no known answers. One area of otherwise unexplored cultural knowledge using CCT models is that of distance predictions. While research on distances between geographical locations has benefited from other methodologies such as multidimensional scaling techniques, it has done so without the help of cognitively based variables that allow us to quantify the degree of knowledge in a collection of informants. This talk will present a metric response CCT model that will take individual performance abilities along with item difficulty measures into account when constructing distances between objects that satisfy the triangle inequality.

24/07 16:20
The Slate

Revisiting the Decision Boundary Debate

James Palestro, Emily Weichart, Per Sederberg, Brandon Turner
The Ohio State University, United States of America

Traditional models of choice response time assume that sensory evidence accumulates for choice alternatives until a threshold amount of evidence has been obtained. Although some researchers have characterized the threshold as varying randomly from trial to trial, these investigations have all assumed that the threshold remains constant across time within a trial. Despite decades of successful applications of these models to a variety of experimental manipulations, this fixed threshold assumption has recently been called into question, and a collapsing bound alternative has been proposed instead. Here we investigate the fidelity of the collapsing bound assumption by assessing relative model fit to data from a highly constrained experimental design. Our design involves a within-subject mixture of two classic paradigms: the interrogation and the free response paradigms. With this design, we are better able to disambiguate the evidence accumulation process from the elicitation process, thereby facilitating a more rigorous investigation of the collapsing bound assumption.

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Tiered
Scarman

Sequential search behavior changes according to distribution shape despite having a rank-based goal

John Wong[1], Jonathan Nelson[2] and Lael Schooler[3]
[1] Max Planck Institute for Human Development, Germany, [2] University of Surrey, [3] Syracuse University

In the area of sequential choice, the 'Secretary Problem' has been a prominent paradigm within the study of optimal stopping for sequential search tasks. Most recent studies of the Secretary Problem present decision makers with the relative ranks of options. A recurring finding is that decision makers tend to end their search earlier than optimal decision strategies (e.g. Helversen, Wilke, Johnson, & Schmid, 2011; Seale & Rapoport, 1997, 2000). By revealing only relative ranks of options or items, issues of learning and incomplete knowledge are avoided; however, this leaves open the question of how sensible human decision makers are when they know more about the distribution of items. Rather than presenting merely ranks to decision makers, we presented numerical values drawn from three distinct distributions in which relatively high value items were scarce, evenly distributed, or abundant. We found that they selected their items earlier than they would if they utilized the optimal selection rule. More importantly, in contrast to the conclusion of Kahan, et al. (1967), we found the selection points of decision makers were sensitive to the underlying distribution. In contrast, the optimal strategy is totally based on quantile ranks regardless of the type of distributions.

Explaining multiple cue judgment with a mixture model that combines exemplar with cue abstraction processes

24/07 16:20
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Scarman

Rebecca Albrecht[1], Janina Anna Hoffmann[2], Jörg Rieskamp[1], Timothy Pleskac[3] and Bettina vonHelversen[4]

[1] University of Basel, Switzerland, [2] University of Konstanz, Germany, [3] Max Planck Institute for Human Development, Germany, [4] University of Zurich, Switzerland

Exemplar and cue-abstraction models are well-established tools to understand categorization and judgment processes. However, many models in this area are limited by paying little attention to (1) the finding that judgments are often the result of a mixture of exemplar and cue-abstraction processes and (2) that in case of exemplar processes an outcome could be the results of a competitive retrieval process of exemplars in memory. We developed a new exemplar-based competition model with cue-abstraction (CX-COM) that addresses these both limitations. CX-COM assumes that first past exemplars compete for retrieval and second the resulting judgments from the retrieved exemplars' are adjusted following a cue-abstraction process. We tested the new model in two experimental studies.

Study 1 tested whether cue-based adjustments occur. Study 2 assessed the competitive exemplar retrieval component, which predicts that variability in judgments increases with the difference in judgment values of competing memory items. Additionally, we conducted a quantitative analysis by building a framework of seven cognitive models that allow for maximal discrimination between model components.

We find that the CX-COM model is best suited to explain human judgments. Quantitatively the model provides the best fit. In Study 1 we find adjustment patterns predicted by exemplar models including a cue-abstraction process. In Study 2 we find across-item variability predicted by a competitive memory component. Our research shows the importance of considering variability in addition to mean values in judgment research.

Noisy morals: Variability of moral value judgments in a constant environment

24/07 16:20
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Scarman

Alexandra Surdina, Adam Sanborn

University of Warwick, United Kingdom

What we value defines who we are. Moral values are known to make up a part of our sense of identity. Yet, at the same time, moral judgments vary in response to external change: For example, people's moral decisions can be biased by imposing time constraints, or inducing prior choices; choosing a morally bad option inspires people to make up for it in the future, while a morally good choice legitimises a subsequent immoral action - phenomena known as moral licensing and cleansing. Overall, moral choice appears to be responsive to changes in the environment. But do moral judgments change as time passes and people do neither learn nor do anything new? Are our moral values consistent over time, or are we different people from moment to moment?

Using a mixed effect modelling approach, we studied repeated responses to the moral foundations questionnaire [Graham, J., Nosek, B. A., Haidt, J., Iyer, R., Koleva, S., & Ditto, P. H. (2011). Mapping the moral domain. Journal of personality and social psychology, 101 (2), 366]. Comparing models with diagonal and full covariance matrices capturing a full spectrum of foundations versus only two foundation types, we found that a dual-type model not allowing for inter-type interactions is the best fit. We conclude that morality is fundamentally noisy, with a structure encompassing at least two separate underlying stochastic processes: One process responsible for judgments related to harm and fairness, and another influencing moral judgments involving loyalty, authority, and purity.

24/07 16:40
The Slate

Sequential Sampling Models with Variable Boundaries and Non-Normal Noise: A Comparison of Six Models

Andreas Voss

Heidelberg University, Germany

One of the most prominent response time models in cognitive psychology is the drift diffusion model: Typically, diffusion models are applied to fast and easy perceptual tasks. While diffusion models have been tested exhaustively for such fast tasks, it is unclear whether model fit is still optimal when tasks are more difficult and thus require a longer phase of information accumulation. In this case, for example, a collapsing of decision bounds may commence when the correct response is not immediately obvious, or, when tasks require the combined consideration of different attributes, participants may jump to conclusions, which cannot be modeled adequately when a constant drift and normal noise is assumed. In the present project, I compare the fit of six different versions of diffusion models to data from an easy single-stimulus task, and a more difficult multi-stimulus task, which are completed both under speed and under accuracy instructions. The following models were applied: (1) A standard diffusion model; (2) a collapsing boundary model with total collapse; (3) a model with early adaptation of boundary separation; (4) a variable-bounds model allowing for an initial adaptation of thresholds and a later total collapse; (5) a model with Cauchy distributed noise, allowing for large jumps in the decision accumulation; and (6) a model with stable distributed noise where the stability parameter alpha is fitted to data. Across the 4 experimental conditions (task x instruction), Model 6 fitted data best.

Decisions from Experience: Modeling Choices due to Variation in Sampling Strategies

24/07 16:40
Tiered
Scarman

Neha Sharma[1] and Varun Dutt[2]

[1] Indian Institute of Technology, India, [2] Indian Institute of Technology Mandi

Decisions from Experience (DFE) research involves a paradigm (called, sampling paradigm), where decision-makers search for information before making a final consequential choice. Although DFE research involving the sampling paradigm has focused on accounting for information search and final choices using computational cognitive models. However, this research has yet to investigate how computational models would account for final choices for participants with different sampling strategies during information search. In this paper, we perform an individual-differences analysis and test the ability of computational models to explain final choices of participants with different sampling strategies. More specifically, we take an Instance-Based Learning (IBL) model, which relies on recency and frequency processes, and we calibrate this model to final choices of participants exhibiting more-switching (piecewise) or less-switching (comprehensive) between options in different problems. Our results indicate more reliance on recency and frequency of information among participants exhibiting piecewise strategy compared to comprehensive strategy. Overall, the IBL model is able to account for piecewise strategy better compared to comprehensive strategy. We highlight the implications of our results for DFE research involving information search before consequential decisions.

Integrating cue abstraction with retrieval from memory: A learning approach

24/07 16:40
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Scarman

Janina Anna Hoffmann[1], Rebecca Albrecht[2] and Bettina vonHelversen[3]

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When making a judgment, such as evaluating the food in the cafeteria, it has been argued that people select among two kinds of judgment strategies: a capacity-limited abstraction of knowledge and a similarity-based retrieval of past instances. To disentangle these strategies, past research has usually investigated which strategies describe judgments best at the end of learning, assuming that people consistently pursue the same strategy over time. The question of how strategies evolve over time and change as a function of learning has received less attention. The current work aims to fill this gap by formulating a learning model that develops a preference for one over the other strategy over time, thereby adjusting the relative importance of different cues and past exemplars during learning. In simulations, we explored how well the learning model captures important findings in judgment research. Replicating empirical results, we found that the learning model picks up linear relationships faster than nonlinear ones and weighs knowledge abstraction more heavily than exemplar retrieval in these linear tasks. Furthermore, it also shows more accurate predictions beyond the training range in linear than nonlinear tasks. In sum, these

results suggest that a learning model integrating knowledge abstraction and exemplar retrieval may provide a suitable tool for understanding learning processes in human judgment.

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Scarman

What is the nature of decision noise in random exploration?

Siyu Wang, Robert Wilson
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Many decisions involve a tradeoff between exploring options that are unknown and exploiting options we know well. Striking the right balance between exploration and exploitation is a hard computational problem and optimal solutions exist in only the simplest settings. One particularly effective strategy, used by both humans and animals, is choice randomization. In this strategy, random 'decision noise' perturbs the decision process, meaning that high value 'exploit' options are not always chosen and exploratory choices are sometimes made by chance. In this work we investigate the properties of this decision noise, in particular, whether it is generated internally, within the brain, or arises externally, in the input from the world. In particular we used a simple explore-exploit task, adapted from our previous work, in which we had people make the exact same explore-exploit choice twice. If decision noise is externally driven, then people's choices should be identical both times. Meanwhile, if noise is internally driven, the extent to which their choices are consistent should be determined by the level of the internal noise. By analyzing behavior on this task using both model-free and model-based approaches, we were able to show that, while both types of noise are present in explore-exploit decisions, the contribution of internal noise to random exploration far exceeds that contributed by the stimulus. This suggests that decision noise for random exploration is driven a central source that is modulated in the service of exploration.

24/07 17:00
The Slate

A Race Model for Multiple Stopping Rules in Decision Making

Mario Fific
Grand Valley State University, United States of America

A parallel race model is proposed to select among multiple stopping rules and to determine a stopping pattern and a threshold stopping value. The model is called the Cast-Net model as it selects the stopping rule by randomly drawing from a parameter space spanned by a range of possible stopping rule values. It is hypothesized that a decision maker controls the span of parameters for the stopping rules' values. The model synthesizes the three major stopping rules (critical difference, runs, fixed-sample size) the sequential sampling, the variable threshold approach, and the parallel processing structure - in one theoretical framework. The model was tested in a deferred decision making task, in which subjects are asked to open an optional number of either positive or negative recommendations about the quality

of products, and to make the best decision. The task was modeled in the context of a shopping situation, which included varying both the time pressure and reliability of recommendation. The Cast-Net model was compared to single stopping rule models by calculating the likelihood of different stopping rules, given the observed distribution of stopping patterns of recommendations, jointly for both correct and incorrect decisions. The results indicated that the Cast-Net model provides reasonable theoretical grounds of how different simple stopping rules can be combined within one decision making model.

Quantum Entanglement, Weak Measurements and the Conjunction and Disjunction Fallacies

24/07 17:00
Tiered
Scarman

Torr Polakow[1] and Goren Gordon[2]

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A novel quantum cognition model is proposed to address the conjunction and disjunction fallacies. This model represents each concept as a separate qubit and the measurement process as a weak measurement. In order to evaluate our model we conducted an on-line survey questionnaire that addressed several conjunction and disjunction fallacies scenarios that included four different concepts. The novel model enables us to calculate a quantitative measure of quantum entanglement for each participant and each question. We show that irrational judgment is represented by an entangled quantum state, whereas a separable state represents a rational judgment, in both conjunction and disjunction fallacies. Following individual participants' quantum cognitive representation throughout the questionnaire shows their entanglement dynamics. These results suggest a deeper connection between the quantum representation of cognitive concepts and the ensuing irrational judgments, namely, that quantum entanglement between mental states are correlated to irrational behavior regarding these concepts.

Estimating and testing intra-individual multiple-systems and -process models

24/07 17:00
Space 41
Scarman

Maarten Speekenbrink

University College London, United Kingdom

Multiple systems and process models are ubiquitous in psychology. However, the evidence for single agents being guided by multiple systems/processes (MS/P) seems more anecdotal than definitive. Generally, the evidence relies on between-subjects differences. For example, Scheibenhenne, Rieskamp & Wagenmakers (2013) used a mixture modelling approach to show that different people use different strategies within a task, but not that a single person relied on different strategies within a task. Stronger evidence for MS/P requires showing that a single agent relies on different strategies over time. In previous work (Visser & Speekenbrink, 2014), we

used hidden Markov models to identify key markers of MS/P in single agents. Here, I will expand upon this work and introduce hierarchical hidden Markov models as a general framework to study MS/P, and discuss stochastic methods to estimate these models, relying on a combination of sequential Monte Carlo and more traditional MCMC techniques. The modelling framework is applied to data from a category learning experiment where the categories slowly shifted between a simple rule and an information integration structure.

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Visser, I., & Speekenbrink, M. (2014). It's a catastrophe! Testing dynamics between competing cognitive states using mixture and hidden Markov models. In P. Bello, M. Gaurini, M. McShane, & B. Scassellati (Eds.), Proceedings of the 36th annual meeting of the cognitive science society (pp. 1688-1693). Austin, TX: Cognitive Science Society.

Subset System: Mathematical Foundation for Relational Semantics

24/07 17:00
Space 43
Scarman

Jun Zhang, Yinbin Lei

University of Michigan, United States of America

A "subset system" (V, E) refers to an arbitrary collection E of subsets of a ground set V. Following observation that any subset system induces a preorder (reflexive and transitive) and a tolerance (reflexive and symmetric) binary relation on elements of V, we define, in analogous to topology but in a much relaxed setting, notions of neighborhood, separation, specialization order, clique, block, etc. This leads to, in a generic way, accumulation points (used to address convergence of a sequence) and isolation points (after complementation) with respect to any subset of V. Then, by taking advantage of the closure operator Cl associated with any subset system, the notions of boundary, interior, exterior are defined, and their relationships to accumulation/isolation points are preserved without assuming Cl to be (the more restrictive) topological closure. The fixed points of Cl forms an intersection-closed subset system, called "closure system" or Concept Lattice in the context of Formal Concept Analysis. We then investigate the notions of "independence/dependence" (as used in matroid) and "feasibility/accessibility" (as used in antimatroid), which additionally imposes on Cl the Steinitz-MacLane Exchange or Anti-Exchange axiom, respectively. Invoking these axioms locally (i.e., on a fixed subset A of V) leads us to a pre-order relation for points outside Cl(A). Applying our approach to Knowledge/Learning Spaces as special examples, we demonstrate how subset system semantics provide a versatile modeling language to axiomatically handle objects, features, contexts, knowledge, and their acquisition and query.

Recency-weighted incremental learning

25/07 09:00
The Slate

Kristjan Kalm
Medical Research Council, United Kingdom

Human learning and perception can be severely biased towards more recent events. Recency bias has been observed in sensory tasks such as orientation and spatial frequency judgement [1,2], and repetition learning [3]. However, recency bias has been mostly ignored by learning models. Here we present an incremental Markovian approach to learning where the model of the environment is a time-decaying mixture of past experiences. We describe how standard Markovian inference methods, such as Bayesian filtering, fail to replicate essential features of incremental learning. We propose an alternative Markovian approach where the latent state space is a mixture of previous states representing the time-decaying utility of the past sensory states. Finally, we compare the predictive power our approach to both experimental data and alternative incremental learning models.

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Data informed cognitive modelling of offshore emergency egress behaviour

25/07 09:00
Tiered
Scarman

Jennifer Smith, Mashrura Musharraf, Brian Veitch
Memorial University of Newfoundland, Canada

This paper applies a cognitive modelling approach to model decision making of naive subjects in virtual emergency situations. Virtual environments (VE) can be used as a virtual laboratory to investigate human behaviour in simulated emergency conditions. Cognitive modelling methodology and human performance data from VEs can be used to identify the problem solving strategies and decision making processes of general personnel in offshore emergency egress situations. This paper demonstrates the utility of decision trees as a cognitive tool for two main purposes: 1) assessing VE training curriculum and 2) predicting human behaviour. To show these capabilities, the results of two empirical studies are compared using a decision tree induction approach. The first experiment investigated the learning and inference process of participants trained using a lecture based teaching (LBT) approach. The second experiment used another pedagogical approach: simulation-based mastery learning (SBML). Overall, decision trees were found to be a useful method for evaluating the efficacy of VE training, and as a basis for predicting individuals' decision-making performance.

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Scarman

A challenge to the independent-cueing assumption: backward serial recall of chunked lists

Jeremy B. Caplan, Yang S. Liu
University of Alberta, Canada

A near-consensus exists in theories of immediate serial recall that serial recall proceeds from one cue to the next, without regard to the outcome of the prior recall (Henson et al., 1996). This independent-cueing assumption is compatible with one major class of models- positional-coding- but at odds with the other major class of models- associatve chaining. We present data on serial recall of chunked and unchunked, nine-consonant lists, where chunked lists were temporally grouped into three groups of three letters. The influence of chunking on serial-recall in the backward direction was the mirror-image of the influence of chunking on serial-recall in the forward direction. In other words, recall direction interacted with serial position but not with output-position. With the independent-cueing assumption, SIMPLE a well developed positional-coding model, was unable to fit the effects of chunking. Results suggest the independent-cueing assumption may need to be removed from positional-coding models, and adds to the growing argument that associative chaining needs to be reconsidered.

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Scarman

Lindblad equation in quantum-like models of decision making in different contexts

Irina Basieva, Emmanuel Pothos
City University London, United Kingdom

Application of the quantum probability theory (QPT) to problems of decision making allows for a natural explanation of a number of paradoxes observed in cognitive psychology. Effects such as disjunction effect, conjunction effect, question order effect have been elegantly described by the QPT, by means of exploiting the phenomena of interference of probability amplitudes.

Still, the existing quantum-like models do not account for such important aspects as the choice of time moment for the measurement step. Considering that quantum state dynamics described by the Shroedinger equation is forever oscillating, the measurement would very often produce opposite outcomes depending on time moment of the measurement (e.g., pi or pi/2).

Quantum states governed by the Lindblad equation in most cases converge to a stable state, which in itself can be considered a state after measurement. Here, prolonged interaction with environment plays the same role as momentary interaction with a measurement device (often described by a projector). Incorporating the paradigm of interacting quantum system and classical environment to cognitive quantum-like models requires not only more sophisticated mathematical tools, but also new interpretations of mental states and role of context in decision making.

We analyse how particular relations between Hamiltonian and Lindblad operators lead to essentially different kinds of mental state dynamics (with stabilisation

or without, resulting in a uniform mixture or not-uniform, maximally decoherent or not). In our interpretation, we distinguish mental processing of "isolated" task and interaction with (unknown or rapidly changing) environment, which may or may not allow direct computation.

A nearly universal, but very slow, 'blank slate' learning algorithm for inverse inference

25/07 09:20
The Slate

Paul M.B. Vitanyi[1] and Nick Chater[2]

[1] University of Amsterdam, [2] Warwick Business School, United Kingdom

Bayesian models of cognition view many aspects of perception, categorization and learning as inverse probabilistic inference. Specifically, these problems are often modelled as processes of inferring probabilistic models from samples of data that are generated from that model (e.g., sensory or linguistic input). Under what conditions is it possible to recover the model exactly by some computational learning process? It is clear that models which are not computable cannot be recovered, because they cannot be represented by a computable learner. Models with arbitrary real-valued parameters cannot be learned, because such parameters correspond to an infinite stream of random digits which cannot be generated by a finitely specified computational process. Bayesian cognitive science typically restricts attempt to computational probability distributions, from stochastic phrase structure grammars, to graphical models or all kinds. We outline a 'blank slate' learning algorithm with minimal built-in assumptions which takes an limitless stream of data and sequentially proposes probabilistic models (represented as programs) that potentially generated that data; as more data is encountered, the algorithm will switch from one proposal to the next. At some point, it will 'stick' to a proposed probabilistic model; and with probability 1, this will precisely identify the correct model (e.g., the precise stochastic phrase structure grammar or Markov random field, with exactly specified parameters). The algorithm works if the data is sampled i.i.d., or is generated by a Markov chain. Where these assumptions are satisfied, the model predicts future data as well as is possible. However, the learning algorithm is extremely slow.

Modelling Workload of a Virtual Driver

25/07 09:20
Tiered
Scarman

Jan-Patrick Osterloh[1], Jochem W Rieger[2] and Andreas Luedtke[1]

[1] OFFIS Institute for Information Technology, Germany, [2] Carl von Ossietzky University

In many transportation modes, automation is added to increase comfort, efficiency, or to reduce human errors. Automation has a direct impact on the drivers workload, which can even be higher then without automation. In this paper we propose the development of a virtual driver that can predict human workload in early design phases of automation and assistant systems. We describe the workload model in a closed-loop simulation and an early validation.

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Scarman

Estimating semantic networks from fluency data

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Semantic networks are used in psychology to represent how semantic knowledge is organized. It has been suggested that the structure of semantic networks can explain differences in the memory ability of patients populations (such as those with Alzheimer's or schizophrenia) as well as variation in healthy adults. Nonetheless, estimation of semantic networks remains an elusive problem. Numerous techniques exist to infer semantic networks from memory retrieval data, but these techniques can be time consuming and often rely on purely statistical methods that are not grounded in any psychological theory or empirical results. We present a Bayesian model for estimating semantic networks based on the random walk model of memory retrieval (Abbott, Austerweil, & Griffiths, 2015). Participants completed a repeated version of the semantic fluency task (i.e., 'name as many animals as you can in three minutes'). Under the assumption that this data can be modeled as a random walk on a semantic network (i.e., items are listed in the order they first appear in the walk), our model estimates the network that is most likely to have produced that data. We explore how parameters of the model such as the network prior and response time data influence estimation of the network. We validate our model by estimating the similarity of edges inferred by our method compared to the similarity of edges inferred by other leading techniques.

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Scarman

Hilbert Space Multi-dimensional Modeling

Jerome Busemeyer[1] and Zheng Wang[2]
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We present general procedures for constructing, estimating, and testing Hilbert space multi-dimensional (HSM) models, which are based on quantum probability theory. HSM models can be applied to collections of K-different contingency tables obtained from a set of p variables that are measured under different contexts. A context is defined by the measurement of a subset of the p-variables that are used to form a table. HSM models provide a representation of the collection of K-tables in a low dimensional vector space, even when no single joint probability distribution across the p-variables exists. HSM models produce parameter estimates that provide a simple and informative interpretation of the complex collection of tables. Comparisons of HSM model fits with Bayes net model fits are reported for a new large experiment, demonstrating the viability of this new model. We conclude that the model is broadly applicable to social and behavioral science data sets.

Belief Revision by Learning Indicative Conditionals: Selecting Among Doubly Bayesian Models using Bayes Factors

25/07 09:40
The Slate

Henrik Singmann[1], Stephan Hartmann[2] and Quentin F. Gronau[3]

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Bayesian Belief revision provides a formal and rational framework for how agents should update their beliefs in light of new probabilistic information using Bayes' rule or Jeffrey's rule. One question that is as of yet unanswered in theoretical as well as empirical terms is how agents update their beliefs if the new information is not a proposition (i.e., an event or the probability of an event), but a conditional statement of the form "If A then B", which is usually understood as the conditional probability $P(B|A)$. Learning a conditional within this framework can be characterized as updating a prior probability distribution F by conditioning on the conditional probability resulting in the posterior probability distribution F'. We compared a variety of plausible and rational updating schemes on a large data corpus ($N > 100$) in which we could estimate both, participants' prior probability distributions before they learned the conditional as well as their posterior distribution after they learned the conditional. The different schemes were instantiated as hierarchical Bayesian cognitive models and we employed Bayes Factors to select among the different schemes.

Comparing the Input Validity of Model-based Visual Attention Predictions based on presenting Exemplary Situations either as Videos or Static Images

25/07 09:40
Tiered
Scarman

Bertram Wortelen[1] and Sebastian Feuerstack[2]

[1] Oldenburg University, Germany, [2] OFFIS e.V.

Functional cognitive models are used to explain observed human behavior. Applying such models to predict behavior requires generalization of the model to be applied in different application domains but also a careful consideration of model input data validity. Visual attention models have already been validated in various domains. But elicitation techniques to collect valid input data that is reproducible by others are still missing. For visual attention prediction model input data is determined mainly based on discussion between experts and individual experience, which is difficult to reproduce. We use a software tool to ensure input validity. The tool helps users to create attention models. It uses images of the situations that are investigated for stimulating the imagination of users to put themselves into these situations. An experiment (n=40) showed that using looping videos instead of static images stimulates imagination in a different way. It has an effect on the models generated by the users and needs careful consideration.

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Scarman

Evaluating the Role of Prior Knowledge and Random Guessing in Long-Term Memory

Pernille Hemmer, Kimele Persaud
Rutgers University, United States of America

An important question of long-term memory is what happens to memory traces over time. Previous research suggests that although memory traces can be quickly formed and retained, associations for arbitrary object-location pairings are formed slowly and quickly forgotten (Lew, et al., 2015). Observers are assumed to either recall target information with noise, misassociate target and cue information, or guess randomly. In contrast, meaningful associative information in the stimulus environment is known to influence episodic memory, and improve average accuracy, which remains stable over time (Persaud & Hemmer, 2016). Observers are assumed to integrate prior expectations for the statistical regularities of the environment with noisy episodic content at recall - without guessing randomly. Here, we sought to reconcile these contradictory findings. In a series of experiments, we assessed memory for associations with varying degrees of meaningfulness, including associated objects in meaningful locations, associates objects in random locations, and random objects in random locations. We found that, while arbitrary associations are fragile and account for the difficulty in forming and retaining information, prior meaningful associations are well formed, and thus less fragile and can help sustain episodic memory over time. We fit the Misassociations model (Lew et al., 2015) and found that most errors in memory result from misassociations and an influence of prior knowledge, not random guessing - finding that there is no random guessing in LTM for semantically associated, ecologically valid stimuli, and that standard findings have been an artifact of experimental design. Implications for models of long-term memory are discussed.

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Scarman

Measuring the utility for money in a riskless context: evidence on separable representations

Raffaello Seri[1], Michele Bernasconi[2] and Christine Choirat[3]
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The utility of money, assigning measures of subjective value to physical amounts of money, is a fundamental concept in decision theories. Most modern empirical literature focuses on preferences over money gambles, eliciting jointly the utility for money and the rules used to combine probabilities of money-utilities. In this paper we investigate the possibility to measure the utility of money directly in a riskless context. We conduct an experiment in which participants are asked to suppose they receive a monetary gift $d1$ and to indicate a monetary response $d2$ which they would want in order to feel in some proportion p as happy as the amount $d1$ would make them. The experimental framework, based on Stevens' ratio magnitude production, is similar to the one used in a classical investigation by Galanter. Stevens' approach

is often criticized because of lack of mathematical and psychological foundations. However, recently, an important stream of research has clarified the conditions justifying ratio estimations and productions. In particular, two axioms are essential to obtain meaningful representation measures from subjects' ratio scaling: multiplicativity and commutativity. The evidence is in general in favor of commutativity, but against multiplicativity. This is consistent with models of so-called separable representations incorporating the notion that various and independent distortions occur both in the assessment of subjective intensities and in the determination of subjective ratios. We test both axioms and find substantial evidence for commutativity, but against multiplicativity. We provide estimates of the psychophysical functions of interest, including the utility function for money.

Resource-rational analysis

25/07 10:00
The Slate

Falk Lieder
UC Berkeley, United States of America

Resource-rational analysis bridges the gap between the computational and the algorithmic level of analysis via a series of intermediate levels. Each successive level incorporates increasingly more realistic assumptions about the mind's cognitive architecture and its computational constraints. The key idea is to push the notion of rationality, often used in defining computational-level models, deeper toward the algorithmic level. This leads to a simple recipe for reverse-engineering the mind's cognitive strategies by deriving optimal algorithms for a series of increasingly more realistic abstract computational architectures. I will illustrate this approach with three case studies: resource-rational anchoring-and-and adjustment, utility-weighted sampling, and automatically deriving rational heuristics for risky choice.

Modeling of Visual Search and Influence of Item Similarity

25/07 10:00
Tiered
Scarman

Stefan Lindner, Nele Russwinkel, Lennart Arlt, Max Neufeld, Lukas Schattenhofer
TU Berlin, Germany

A modeling approach addressing visual search in an array of items of differing similarity is introduced. The model is able to capture the effects found in a study that varies target-distractor similarity (low vs. high), distractor-distractor similarity (low vs. high) of icons, target presence (present vs. absent) and the set size (8, 16 or 24 icons). To be able to simulate human visual search in such a task with original ACT-R mechanisms we implemented a hybrid search strategy that combines parallel and serial search. The presented model can provide useful insight for researchers interested in modeling tasks containing visual icon search.

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Scarman

A hierarchical Bayesian model of memory for when based on Experience Sampling data

Simon Dennis[1,4], Vishnu Sreekumar[2], Nathan Evans[3] and Paul Garrett[1]

[1] University of Newcastle, Australia, [2] National Institutes of Health, [3] Vanderbilt, [4] Unforgettable Technologies LLC

Participants wore a smartphone, which collected GPS, audio, accelerometry and image data, in a pouch around their necks for a period of two weeks. After a retention interval of one week, they were asked to judge the specific day on which each of a selection of images was taken. To account for people's judgements, we proposed a mixture model of four processes - uniform guessing, a signal detection process based on decaying memory strength, a week confusion process, and a event confusion processes in which the sensor streams were used to calculate the similarity of events. A model selection exercise testing all possible subsets of the processes favoured a model that included only the event confusion model. GPS similarities were found to be the most significant predictors, followed by audio and accelerometry similarities and then image similarities.

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Canonical systems of random variables in contextuality analysis

Ehtibar Dzhafarov[1], Victor Cervantes[1] and Janne Kujala[2]

[1] Purdue University, United States of America, [2] University of Jyvskyl, Finland

Random variables representing measurements, broadly understood to include any responses to any inputs, form a system in which each of them is uniquely identified by its content (that which it measures) and its context (the conditions under which it is recorded). Two random variables are jointly distributed if and only if they share a context. In a canonical representation of a system, all random variables are binary, and every content-sharing pair of random variables has a unique maximal coupling (the joint distribution imposed on them so that they coincide with maximal possible probability). The system is contextual if these maximal couplings are incompatible with the joint distributions of the context-sharing random variables. We propose to represent any system of measurements in a canonical form and to consider the system contextual if and only if its canonical representation is contextual. As an illustration, we establish a criterion for contextuality of the canonical system consisting of all dichotomizations of a single pair of content-sharing categorical random variables.

Stochastic hypothesis generation in human probabilistic inference

25/07 10:40
The Slate

Ishita Dasgupta

Harvard University, United States of America

A growing body of literature supports the claim that humans perform Bayesian inference in several everyday cognitive tasks. However, several cognitive domains have combinatorially large latent spaces, and exactly normalizing the posterior over these huge spaces is intractable. In this talk I will present an resource-rational algorithm based on Markov chain Monte Carlo that approximates this calculation by taking a limited number of samples, i.e. generating a limited number of "hypotheses", and making a probability judgment based on this set of hypotheses. This model replicates several observed cognitive biases in human probabilistic inference. I will focus on our model's explanation of unpacking effects like sub-additivity and super-additivity.

Spatial relationships and fuzzy methods: Experimentation and modeling

25/07 10:40
Tiered
Scarman

James Ward[1], Robert St. Amant[2] and Maryanne Fields[3]

[1] U.S. Army Research Office, [2] North Carolina State University, United States of America, [3] Army Research Laboratory

This paper describes an experiment and fuzzy set models in the domain of linguistic labels for simple spatial relationships: for example, that one object is "in front of" or "to the right of" another. Input to the models was generated by robot sensors (camera and distance sensors), from a viewer perspective on different configurations of two objects. Performance of the models is is qualitatively similar to human judgments; performance is also quantitatively similar to that of a model working from an environmental bird's-eye view. Such models are one component of a robot's interpretation of the context of human activity.

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Lotteries versus Investments: Exploring effects of financial framing on response times in risky choice.

Ashley James Luckman, Jörg Rieskamp
University of Basel, Switzerland

Several studies have shown that behaviour in simple monetary gambles, as are typically used in experimental investigations of risky choice, may differ from behaviour in financial decisions, such as investment or insurance decisions, with matched content (Kusev et al., 2009, Vlaev et al., 2010). We explore this particular framing effect further by considering both participants' choices and associated response times. Inclusion of response times has the potential to provide a richer account of how decision making is affected by financial framing. For instance, differences could be due to changes in decision thresholds, indicating a similar but more cautious decision process, or in how evidence is accumulated. 200 participants were recruited through mTurk, with half completing 127 choices between binary lotteries, and half completing 127 choices between stocks with binary outcomes. Lotteries and stocks were matched so that for each lottery choice there was a corresponding stock choice with identical pay-offs and probabilities. Both mixed and gain-only lotteries were used. Considering only choice data, using Expected Utility models no differences in risk-aversion or consistency were found between the stock and lottery framing. Based on the literature differences in risk-aversion were expected. To consider response times, versions of Decision Field Theory (Busemeyer & Townsend, 1993) and the Linear Ballistic Accumulator (Brown & Heathcote, 2008) were fit to both choice and response time data simultaneously to test for differences in thresholds or evidence accumulation between conditions. Differences in predictions between the two model architectures are also considered.

25/07 10:40
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Scarman

The lognormal-race model of response inhibition: A simple process model of performance in the stop-signal paradigm

Dora Matzke[1] and Andrew Heathcote[2]
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The cognitive concept of response inhibition is frequently investigated using the stop-signal paradigm. In this paradigm, participants perform a two-choice response time (RT) task that is occasionally interrupted by a stop signal that instructs participants to withhold their response. Stop-signal performance is typically modeled as horse race between two competing processes: a go process that is initiated by the primary task stimulus and a stop process that is triggered by the stop signal (Logan & Cowan, 1984; Matzke, Love, & Heathcote, 2016). If the go process wins the race, the primary response is executed; if the stop process wins the race, the primary response is inhibited. Although the horse-race model allows for the estimation of the latency of the unobservable stop response, it does so without accounting for accuracy on the primary task and by lumping together the decision and non-decision components of stopping latencies. Here we address these limitations and introduce a simple process model of response inhibition based on the lognormal race (Heathcote

& Love, 2012). We augment the model to account for failures to trigger the go and stop processes and for the strategic slowing of primary task RTs over the course of the experiment. We explore the operating characteristics of the proposed model, apply it to stop-signal data featuring the manipulation of task difficulty, and discuss the strengths and weaknesses of the approach.

Mental Sampling in Multimodal Representations

25/07 11:00
The Slate

Jian-Qiao Zhu[1], Adam Sanborn[1] and Nick Chater[2]
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Both resources in the natural environment and concepts in a semantic space are distributed 'patchily', with large gaps in between the patches. To describe people's internal and external foraging behavior, various random walk models have been proposed. In particular, internal foraging has been modelled as sampling: in order to gather relevant information for making a decision, people draw samples from a mental representation using random-walk algorithms such as Markov chain Monte Carlo (MCMC). However, the sampling patterns that humans and other animals produce have long-range, slowly decaying serial correlations characterized as 1/f-like fluctuations. These fluctuations are not usually produced by simple sampling algorithms such as MCMC. Instead, we propose that mental sampling is adapted to multimodal and/or scale-free representations and is implemented by Metropolis-coupled Markov chain Monte Carlo (MC3), which is one of the first algorithms developed for sampling from multimodal distributions. MC3 involves running multiple Markov chains in parallel but with target distributions of different temperatures, and it swaps the states of the chains whenever a better location is found. Heated chains more readily traverse valleys in the probability landscape to propose moves to far-away peaks, while the colder chains make the local steps that explore the current peak or patch. We show that MC3 can generate 1/f-like behavior when sampling from both unimodal and multimodal distributions, and that aggregating samples to a bound can imitate the 1/f noise observed in reaction times.

Generating Random Sequences For You: Modeling Subjective Randomness in Competitive Games

25/07 11:00
Tiered
Scarman

Arianna Yuan, Michael Tessler
Stanford University, United States of America

Generating truly random sequences is hard. When participants are engaged in a competitive game (e.g., Matching Pennies), the sequences they generate are surprisingly more random than when given explicit instructions to generate random sequences (Rapoport and Budescu, 1992). To explore this phenomenon, we formalized two probabilistic models of Theory of Mind reasoning about subjective randomness. One model (the Fair-Coin model) assumes participants predict their opponents' choices by implicitly assuming that their opponents intend to generate

binary sequences that simulate the outcome of tossing a fair coin. The other model (the Markov model) assumes participants believe that their opponents intend to generate sequences that simulate the outcome of a Markov process with transition probability equal to 0.5. We find that Theory of Mind models of both the Fair-Coin and the Markov definitions of subjective randomness are able to characterize the calibrated subjective randomness that occurs when participants are playing an iterated competitive game (Matching Pennies), but the Markov Model is better than the Fair-Coin Model in simulating the situation where participants need to specify their choice sequences in advance of the game. The current study suggests that the calibrated subjective randomness in competitive games can be explained by the online evaluation of sequence randomness with Theory of Mind reasoning.

A large-scale study examining differences in risk attitude across three choice contexts: financial choices, health care choices, and climate change policies.

25/07 11:00
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Scarman

Clintin Davis-Stober[1], Nicholas Brown[1], Joffre Swait[2] and Vic Adamowicz[3]

[1] University of Missouri, United States of America, [2] Institute for Choice, University of South Australia, [3] University of Alberta, Canada

We report the results of an online study of risk attitude across multiple choice contexts featuring a large (N = 1,596) representative sample of adults from the United States. Participants were presented with multiple framing conditions (gains, losses and mixed gambles) across multiple choice contexts: (a) risky financial choices, (b) risky choices regarding health and mortality, and (c) risky choices regarding potential climate change polices and outcomes. We classified participants according to risk attitude via a Bayesian model based upon p-additive utility representations (Davis-Stober & Brown, 2013; Luce 2010). Our results show substantial heterogeneity of risk attitude type both between and within participants. Framing conditions (gains, losses and mixed gambles) as well as choice context (financial, health or climate change) produced substantial shifts in individual-level risk attitude. These results challenge 'one-size- fits-all' economic models of decision making that feature strict risk aversion or risk neutrality as assumptions. We find that less than 3% of individuals satisfy the reflection effect (Kahneman and Tversky, 1992) for most conditions, i.e., risk aversion for gains and risk seeking for losses. We explore differences in risk attitude between choice contexts which carry implications for medical/health decision making as well as climate change policy.

Stop signal modeling revisited

25/07 11:00
Space 43
Scarman

Hans Colonius[1] and Adele Diederich[2]
[1] Oldenburg University, Germany, [2] Jacobs University Bremen, Germany

Investigating response inhibition in the laboratory often relies on the stop-signal paradigm. Participants perform a response time task (the go task) and, occasionally, the go stimulus is followed by a stop signal after a variable delay, instructing subjects to withhold their response. The main interest is in estimating the unobservable stop-signal reaction time (SSRT), that is, the latency of the stop process, as a characterization of the response inhibition mechanism.

Logan & Cowan (1984, PsychRev) modeled the stop-signal task as a race with stochastically independent go and stop processes. According to the model, a response to the go task in the presence of a stop signal occurs whenever the go process wins the race against the stop process initiated by the stop signal. In the Logan-Cowan race model, under certain simplifying assumptions some statistics of SSRT can be estimated efficiently without making any distributional assumptions. In recent years, a variety of alternative race models, also for variations of the stop-signal paradigm, have been proposed which focus more on the underlying cognitive processes. Neurophysiological studies have shown that the neural correlates of the go and stop processes produce saccadic eye movements through a network of interacting neurons, leading to an interactive race model (Boucher et al. 2007, PsychRev). Here we present a generalization of the Logan-Cowan model that does no longer assume stochastic independence between go and stop processes. It resolves the apparent paradox between behavioral and neural data but nonetheless retains the distribution-free properties of the original race model.

Efficient physical cognition relies on both approximate simulation and sampling

25/07 11:20
The Slate

Kevin Smith
Massachussetts Institute of Technology, United States of America

Using physical reasoning to predict what might occur underlies a wide range of day-to-day behavior, from determining whether a stack of plates in the sink will fall to predicting where to run in order to catch a Frisbee. These predictions require efficiently solving the computational problem of determining how the world will unfold given uncertainty about the locations and properties of objects in the world, and then updating those predictions with new information as the world actually does unfold over time. However, producing a full posterior distribution over possible world outcomes is difficult for two reasons: modeling the world exactly is computationally intractable and forming a full, probabilistic distribution at even a single point in time requires taking a large number of samples from that model. I suggest that people solve these challenges by both approximating the world model using a noisy 'intuitive physics engine' and by efficiently using samples from this engine to produce and update predictions. By studying how people make predictions about where a

ball bouncing around a computerized table will end up and how those predictions unfold over time, I will show evidence for both the use of a noisy physics model, and for cached sample-based updating. These findings suggest that in domains with complex models of the world, we should consider cognitive approximations both to the world model and to the probabilistic updating process.

25/07 11:20
Tiered
Scarman

Applying Primitive Elements Theory for Procedural Transfer in Soar

Bryan William Stearns, John Laird, Mazin Assanie
University of Michigan, United States of America

Detailed transfer of procedural knowledge has been modeled in Actransfer, an extension of ACT-R, by combining the primitive memory operations of productions (PRIMs) with the architecture's procedural learning mechanism citeptaatgen2013nature. This work explores whether these same principles can be applied to the Soar cognitive architecture, which uses different models of working memory and procedural learning. We confirm that these principles can transfer to an unmodified version of Soar. Our research contributes a novel model of skill learning based upon a deeper level of primitive skill composition than described in the PRIM model that is suitable for unbounded working memory architectures, and which yields transfer profiles similar to those revealed in human studies.

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Scarman

A context-dependent random preference approach to the description-experience gap

Michel Regenwetter, Maria Robinson
University of Illinois at Urbana-Champaign, United States of America

According to the description-experience (DE) gap decision makers differ qualitatively in their preferences among lotteries whose outcomes and probabilities they learned from description versus those they learned from experience. A common version of the hypothesis states that decision makers satisfy Cumulative Prospect Theory with overweighting of small probabilities in description but with underweighting of small probabilities in experience. Much existing research on the DE gap uses heuristic scientific methods that are subject to logical reasoning fallacies. We model the heterogeneity of preferences jointly across people, trials and DE contexts. We use polyhedral methods from distribution-free random utility theory to characterize the resulting models and reanalyze published data using frequentist and Bayesian order-constrained inference and model selection methods.

This talk covers part of the paper: Regenwetter & Robinson (2017). "The construct-behavior gap in behavioral decision research: A challenge beyond replicability," Psychological Review.

Survivor Interaction Contrasts for Error Response Times. Part 1: Non-parametric Contrasts for Serial and Parallel Systems

25/07 11:20
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Scarman

Daniel Little[1], Ami Eidels[2], Haiyuan Yang[3], Yanjun Liu[3], Ru Zhang[4] and James Townsend[3]

[1] University of Melbourne, Australia, [2] University of Newcastle, Australia, [3] Indiana University, [4] University of Colorado

Systems Factorial Technology is a theoretically-motivated methodology which aims to differentiate several fundamental attributes of information processing systems. For instance, are multiple sources of information processed in serial or in parallel? Does processing stop after processing one source or continue exhaustively through all sources? Are processes independent or do facilitatory or inhibitory interactions exist between channels? And what is the workload capacity of the information processing system? A key limitation of the SFT approach is that the original theorems (Townsend & Nozawa, 1995) underlying the fundamental predictions for different processing systems are proved only for correct responding. Recent endeavours (Townsend & Altieri, 2012) have extended the analysis of capacity to encompass a general theory of response times conditioned on accuracy. In the present paper, we present a non-parametric theory of architecture identification generalized to correct and error response times by developing survivor interaction contrasts predictions conditioned on correct and errors responses. Our proofs demonstrate firstly that the correct SICs hold regardless of the level of accuracy, and secondly, that the error SICs reflect a symmetry with the correct SICs but with a change in stopping rule.

Adaptive allocation of resources for mental simulation

25/07 11:40
The Slate

Jessica Hamrick

University of California, Berkeley, United States of America

Mental simulation is a powerful ability that allows people to make predictions and inferences about the world by building mental models of the objects, scenes, and agents in their environment and then "mentally simulating" what will happen. Often, however, these mental simulations are noisy and uncertain, meaning that a single simulation does not provide perfect information. This suggests a speed/accuracy tradeoff: if people run multiple simulations, they will get a more reliable estimate of what will happen, but if they run too many simulations, they will spend too much time thinking and not enough time acting. To investigate how many simulations people choose to run, we combined a model of noisy physical simulation with a decision making strategy called the sequential probability ratio test, or SPRT (Wald, 1947). Our model predicted that people should use more samples when it is harder to make an accurate prediction due to higher simulation uncertainty. We tested this through a task in which people had to judge whether a ball bouncing in a box would go through a hole or not. We varied the uncertainty across trials by changing the size of the holes and the margin by which the ball went through or missed

the hole. Both people's judgments and response times were well-predicted by our model, demonstrating that people have a systematic strategy to allocate resources for mental simulation.

Survivor Interaction Contrasts for Errored Response Times. Part 2: Theorems for Poisson Race Models, Diffusion Models, and Initial Data

25/07 11:40
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Scarman

Haiyuan Yang[1], Ru Zhang[2], Yanjun Liu[1], Michael J. Wenger[3], Daniel Little[4], Ami Eidels[5] and James Townsend[1]

[1] Indiana University, United States of America, [2] University of Colorado, [3] University of Oklahoma, [4] University of Melbourne, [5] University of Newcastle

Part 1 continued one of our foremost traditions, namely constructing an extension of systems factorial technology whose theorems and predictions are distribution free and non-parametric. However, we thought it expedient to make sure that ordinary, parameterized models actually do obey tenets and proofs of the more abstract formulation and without seeming unrealistic. Hence, we investigated the most popular of contemporary process models, namely Probability Mixture Diffusion Models and Poisson Race Models. Proofs that correspond to those in the general theory are offered and many simulations supply quantitative detail and furnish additional intuition. Some preliminary data is exhibited.

Information Theory and Stochastic Model Selection in Associative Learning and Memory

25/07 13:10
The Slate

Charles Ransom Gallistel

Rutgers University, United States of America

Two information-theoretic principles, maximum entropy, and minimum description length found a computational model of associative learning that explains cue competition (assignment of credit), response timing, and the parametric invariances. State cues and point cues are linked, respectively, to two stochastic distributions, the exponential and the BernoulliGauss. The stochastic model selected by the computational model specifies the relative code lengths for the most efficient encoding of the data and best predicts the data not yet seen. Its hazard function predicts the timing of conditioned behavior. The minimum-description-length approach to stochastic model selection (Rissanen 1999) enables the computational model to find the stochastic model that maximally compresses the data and best predicts the future.

Distinguishing between evidence accumulation and temporal probability summation in perceptual decision making

25/07 14:40
The Slate

Gaurav Malhotra, Casimir Ludwig, Iain Gilchrist
University of Bristol, United Kingdom

Models of perceptual decision making typically assume temporal integration of a decision variable (e.g. sequential sampling models). However, the sensory input to these models, and therefore the precise input to the decision variable, is typically left unspecified. In contrast, models of early sensory system (e.g. probability summation models) specify that the ideal observer should generate the decision variable by matching a signal template with the stimulus. These models typically assume that the decision variable is not integrated but evaluated at each instant. We investigated how people identify signals in a stimulus that is temporally extended and contained additive and uncorrelated noise. When the signal-to-noise ratio (SNR) of this type of stimuli is varied, both models predict a shift in the reaction time distribution. But the models generate different predictions about how RT distributions shift with a change in SNR and the nature of this shift depends on whether the signal or noise component is varied. In an experiment where participants were asked to identify one of two numeric characters in a noisy animation, we found that the parameters of the fitted Ex-Gaussians shifted in line with the sequential sampling model. We also found the same pattern of parameter shifts irrespective of whether the SNR was manipulated through varying the signal (Session 1) or noise (Session 2). This finding suggests that the decision variable is related to the SNR of the stimulus, rather than the ideal decision variable that represents the difference in matched template responses.

Warm (for winter): Comparison class understanding in vague language

25/07 14:40
Tiered
Scarman

Michael Tessler[1], Michael Lopez-Brau[2] and Noah Goodman[1]
[1] Stanford University, United States of America, [2] University of Central Florida

Speakers often refer to context only implicitly when using language. "It's warm outside" could signal warm relative to other days of the year or just the current season (e.g., warm for winter). "Warm" conveys the temperature is high relative to some comparison class, but little is known about how a listener decides upon such a standard of comparison. We formalize how world knowledge and listeners' internal models of speech production can drive the resolution of a comparison class in context. We introduce a Rational Speech Act model and derive two novel predictions from it, which we validate in an experiment that measures listeners' beliefs about the likely comparison class used by a speaker. Our model makes quantitative predictions given prior knowledge for the domains in question. We triangulate this knowledge with a follow-up language task in the same domains, using Bayesian data analysis to infer priors from both data sets.

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Make-or-break: chasing risky goals or settling for safe rewards?

Pantelis P. Analytis[1], Charley Wu[2] and Alexandros Gelastopoulos[3]

[1] Cornell University, [2] Max Planck Institute for Human Development, [3] Boston University

Humans regularly invest time towards activities characterized by dramatic success or failure outcomes, where critically, the outcome is uncertain ex-ante. How should people allocate time between such make-or-break activities and other safe alternatives, where rewards are a more predictable (e.g., linear) function of time? Although researchers across disciplines in psychology have pointed out to the importance of such decision-making contexts for human behavior, the problem still evades rigorous mathematical analysis. In this paper, we present a formal framework for studying time allocation between these two types of courses of action, and explore (optimal) behavior in both an one-shot and a dynamic version of the problem. In the one-shot version, we illustrate (i) that small changes in people's skill level can lead to drastic changes in the optimal policy due to the non-convex nature of the problem (ii) the role of uncertainty as a motivating factor in how people should allocate time. In the dynamic version of the problem, we formulate both fully rational and boundedly rational strategies, by defining the notion of a giving up threshold, which adaptively dictates when the decision-maker should stop pursuing the make-or-break goal. Comparing different strategies across environments, we investigate the cost of sidestepping the computational burden of full rationality. We then draw connections to the literature on risk-taking, sunk cost fallacy, and drift diffusion models.

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Scarman

Knowledge space theory for polytomous items

Jürgen Heller

University of Tuebingen, Germany

In the spirit of the celebrated Birkhoff theorem, the so-called quasi ordinal assessment spaces (generalizing quasi ordinal knowledge spaces) can be characterized by establishing a one-to-one correspondence to certain binary relations on an extended item set, which contains a positive instance and a negative instance for each of the items (Heller, 2016). It is shown that this construction can be generalized even further to apply not only to dichotomous items, but to polytomous response formats (let it be unipolar, or bipolar), where categories are partially ordered. This componentwise ordering imposes an order on the set of all response patterns. Particular collections of response patterns, which are to be conceived as analogues of (special types of) knowledge structures, can then be characterized through extending the item set by including for each item several instances representing all the possible responses. These collections can be built from data through applying to the extended item set procedures commonly used in knowledge space theory. The presented theory generalizes previous approaches in this direction (Schrepp, 1997). Various applications are discussed, including the analysis of questionnaire data as

they arise in psychological testing (e.g., with response categories such as disagree-neutral-agree), and an integrated representation of knowledge and misconceptions.

Heller, J. (2016). Quasi ordinal assessment spaces for analyzing questionnaire data. Paper presented at the EMPG 2016, Copenhagen.

Schrepp, M. (1997). A generalization of knowledge space theory to problems with more than two answer alternatives. Journal of Mathematical Psychology, 41, 237-243.

A dynamic conflict-based account of intra-trial decision-making

25/07 15:00
The Slate

Emily Weichart, Brandon Turner, Per Sederberg

The Ohio State University, United States of America

The human cognitive system is remarkably flexible and can rapidly adjust to shifting task demands and perceptual inputs. Though there are several theoretical and mathematical models of how and when cognitive control is engaged, recent efforts have been limited to characterizing between-trial effects of conflict. In order to gain a complete mechanistic understanding of the interplay between conflict and cognitive control, we need to examine the dynamics of within-trial processes that underlie decisions. To our knowledge, only two models have attempted to capture cognitive control on a trial-by-trial basis (SSP: shrinking spotlight model, White, Ratcliff et al. 2011; DSTP: dual-stage two-phase model of selective attention, Hbner et al. 2010), each achieving mixed levels of success. The SSP and DSTP models assume an increase in selective attention for the relevant stimulus over the course of a trial. Here, we present a new model of intra-trial effects wherein drift rate is not driven by time, but rather by a dynamic measure of conflict that is based on the accumulators themselves. The conflict-based model provided better fits to data from a standard Eriksen flanker task and a 2-AFC variant of the Stroop task compared to an analogous time-based model (SSP), all without a single additional parameter. Furthermore, our new model produces parsimonious differences in conflict between congruent and incongruent conditions that cannot be captured by a time-varying attentional process. These results suggest that conflict resolution is a result of an intra-trial accumulation process that is agnostic to the simple passage of time.

25/07 15:00
Tiered
Scarman

Degrees of Separation in Semantic and Syntactic Relationships

Matthew Alexander Kelly[1], David Reitter[1] and Robert West[2]
[1] Pennsylvania State University, United States of America, [2] Carleton University

How do humans learn the syntax and semantics of words from language experience? How does the mind discover abstract relationships between concepts? Computational models of distributional semantics can analyze a corpus to derive representations of word meanings in terms of each word's relationship to all other words in the corpus. While these models are sensitive to topic (e.g., tiger and stripes) and synonymy (e.g., soar and fly), the models have limited sensitivity to part of speech (e.g., book and shirt are both nouns). By augmenting a holographic model of semantic memory with additional levels of representations, we present evidence that sensitivity to syntax is supported by exploiting associations between words at varying degrees of separation. Our hierarchical holographic memory model bridges the gap between models of distributional semantics and unsupervised part-of-speech induction algorithms, providing evidence that semantics and syntax exist on a continuum and emerge from a unitary cognitive system.

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Scarman

Efficient Coding Predicts the Universal Law of Generalization

Chris R. Sims
Drexel University, United States of America

Shepard (1987) proposed a 'Universal Law of Generalization', which states that generalization or confusability among perceptual stimuli is an exponentially decaying function of their distance in psychological space. A generalized version expands this to include Gaussian as well as exponential generalization, which is often empirically observed (Nosofsky, 1987). Beyond an empirical result, Shepard also proposed a theoretical account for its origins. His approach, and subsequent work (Tenenbaum & Griffiths, 2001) assumes that perceivers perform inference as to whether a novel stimulus falls in the same 'consequential region' as known exemplars.

In contrast to this account, I offer a new theoretical explanation that is intuitively plausible, broadly applicable, and involves fewer arbitrary assumptions. The theoretical result can be stated precisely as follows: Any physical information channel (possessing a finite channel capacity) that operates efficiently, in the sense of minimizing expected distance between a stimulus and its percept within a metric space, will 'by necessity produce an exponential generalization gradient. In other words, the Universal Law of Generalization is the universal signature of computational rationality maximizing performance subject to processing constraints. This result can be shown as a mathematical proof building on established theorems in information theory, and in particular a branch of information theory known as rate distortion theory.

This result offers a compelling explanation for the universality of the law, for example why honeybees demonstrate the law in spatial generalization. I will also

demonstrate an otherwise surprising result that image artifacts in JPEG image compression also conform to the Universal Law.

On the generalization of knowledge space theory to polytomous items

25/07 15:00
Space 43
Scarman

Luca Stefanutti[1], Pasquale Anselmi[2], Debora de Chiusole[3] and Andrea Spoto[4]

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Schrepp (1997) proposed a generalization of knowledge space theory (KST) to more than two linearly ordered response alternatives. A fundamental result of KST was extended by him: the bijective correspondence between surmise functions for a set Q of items and knowledge spaces (union-closed families of subsets) on Q. With polytomous items, a generalization of set union is the (coordinate-wise) maximum. Schrepp showed that closure under the maximum is a necessary, though insufficient property of a polytomous structure corresponding to a surmise function. Indeed, such structures are characterized by a stronger property, named closure. However, this property does not invoke closures under any kind of binary operations. This aspect gives the impression of a discontinuity between the dichotomous and the polytomous KST. In this talk I introduce two desirable regularity conditions of the polytomous structures (not detectable in the dichotomous case) and show that, under them, closure under the maximum is indeed necessary and sufficient. The first condition states that the atoms of an item are the same at any level of the linearly ordered set of responses; the second establishes a form of independence among the levels. The structures satisfying these two conditions are named regular. Concerning the more general collection of all the (regular and non-regular) structures, we show the existence of a bijective correspondence between the subfamily of the maximum-closed structures and a polytomous extension of the surmise functions. Such "less-regular" structures may be more adequate than the regular ones in modeling certain types of response behaviors.

25/07 15:20
The Slate

A Hierarchical Diffusion Model Analysis of the Approximate Number System

Mark Andrews, Chloe Wider

Nottingham Trent University, United Kingdom

The Approximate Number System (ANS) is the cognitive system that underlies our ability to nonverbally estimate and represent numerical quantities. A typical ANS task involves the presentation of two random displays of dots with the participant choosing the display with the larger number of dots. ANS acuity is then quantified in terms of a Weber fraction that gives the minimum difference in the numbers of dots in the two displays that is noticeable. However, this Weber fraction is calculated solely on the basis of the accuracy data despite the task being a paradigm example of a two alternative forced choice task. It is arguable therefore than an improved measure of acuity can be obtained by modelling performance using a sequential sampling model. In this study, we analyse performance using a Hierarchical drift diffusion model. 60 participants performed 5x100 trials of an ANS task. We modelled their responses with a two barrier diffusion process whose drift rate varied as a linear function of difference in the number of dots in the displays. The parameters of the linear function, the inter-barrier distance, and non-decision time were all modelled hierarchically as random effects. A Gibbs sampler was used to draw samples from the posterior distribution of all unknown variables in the model. Results make it clear that measuring acuity by accuracy alone can be misleading, and a better measure of acuity is in terms of the parameters of the linear model of how the drift rate varies as a function of the stimuli.

25/07 15:20
Tiered
Scarman

Linking Memory Activation and Word Adoption in Social Language Use via Rational Analysis

Jeremy R Cole, Moojan Ghafurian, David Reitter

Penn State, United States of America

This paper investigates how cognition facilitates the adoption of new words through a study of the large-scale Reddit corpus, which contains written, threaded conversations conducted over the internet. Parameters for the cognitive architecture are estimated. Using ACT-R's account of declarative memory, the activation of memory chunks representing words is traced and compared to usage statistics sampled from a year of data. Potential values for decay and retrieval threshold are identified according to model fit and growth rates of word adoption. The resulting estimate for the decay parameter, d, is 0.22, and the estimate for the retrieval threshold parameter, rt, lies between 3.4 and 4.5.

Trials-with-fewer-errors: Feature-based learning and exploration

25/07 15:20
Space 41
Scarman

Hrvoje Stojic[1], Pantelis P. Analytis[2], Peter Dayan[1] and Maarten Speekenbrink[1]

[1] University College London, United Kingdom, [2] Cornell University, United States

Reinforcement learning algorithms have provided useful insights into human and animal learning and decision making. However, they perform poorly when faced with real world cases in which the quality of options is signalled by multiple potential features. We propose an approximate Bayesian optimization framework for tackling such problems. The framework relies on similarity-based learning of functional relationships between features and rewards, and choice rules that use uncertainty in balancing the exploration-exploitation trade-off. We can expect decision makers who learn functional relationships – function learners – to exhibit various characteristic behaviours. First, they will quickly come to avoid exploring options for which the reward function predicts low rewards. Second, if their priors do not correspond to the current environment, then function learners will be led astray by feature information. Third, function learners will explore options to enhance their functional knowledge, i.e., including the uncertainty associated with the impact of features in making their choices. We tested our framework using a series of novel multi-armed bandit experiments (N=1068) in which rewards were noisy functions of two observable features. We compared human behaviour in these problems to solutions provided by Bayesian models. The participants did not perform as well as optimal Bayesian inference as a whole; and indeed some ignored the feature information and relied on reward information only. However, others showed various signatures of Bayesian optimization including being guided by prior expectations about reward functions, taking uncertainty into account when choosing between options, and updating expectations appropriately in light of experiences.

A possible connection between Knowledge Space Theory and Item Response Theory using Information Theory

25/07 15:20
Space 43
Scarman

Stefano Noventa[1], Jürgen Heller[2] and Augustin Kelava[1]

[1] Hector Institut of Education Sciences and Psychology, Universitt Tbingen, Germany, [2] Faculty of Psychology, Universitt Tbingen, Germany

Error parameters represent the noise inherent in any framework designed to assess educational and psychological performances and competences, like Item Response Theory (IRT), Knowledge Space Theory (KST) and Cognitive Diagnostic Modeling (CDM). Generally, they are modeled as conditional probabilities (e.g., guessing and slipping) under an assumption of conditional independence given the ability (IRT), the knowledge state (KST), or the set of skills (CDM) that characterize individuals. Information entropy is suggested as a natural framework to model error parameters, establishing a possible connection between these different theories. In particular, a two-steps model is hypothesized to separate guessing and slipping parameters into a first component (informed guess or mistake) due to the effects of individual ability

on item mastering, and a second one (blind guess or careless error) due to the effects of pure chance on item solving. Based on requiring maximal mutual information between preliminary and actual knowledge, general families of logistic models are derived which account for the probabilities of informed guessing (mastering some item with only partial item-specific knowledge) and mistaking (not mastering some item in spite of item-specific knowledge). Results on the dichotomous case may be extended to arbitrary knowledge structures. Finally, a correspondence between generalized families of Rasch models and Logistic Knowledge Structures is obtained in the limit of minimum mutual information, when latent traits and item characteristics are introduced. Some implications on the assumptions of IRT and Rasch models are also drawn.

25/07 15:40
The Slate

Evidence accumulation versus urgency gating: what's the distinction?

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In recent years, two qualitatively different hypotheses for how sensory evidence is incorporated into decision processes have emerged. The first is the long-established class of evidence accumulation models. This class, which comprises the diffusion decision model, LCA, LBA and others, generally assumes that activation depends on current and past sensory information, possibly with some leakage. The second, more recent hypothesis, is the Urgency Gating Model (UGM). Rather than assume activation depends on an accumulation of evidence, the core assumption of this theory is that activation depends primarily on current sensory evidence (possibly with some temporal smoothing). A temporally increasing urgency signal then influences how this evidence is weighted over time.

A number of studies have been carried out in an attempt to discriminate evidence accumulation models from the UGM. Here, we show that these models are not as distinct as these descriptions make them appear. In fact, the general form of the UGM can be considered a super-model that encodes both accumulation and urgency effects. In different asymptotic regimes, it actually takes the form of a standard drift diffusion model, an OU process, or a pure UGM model. Furthermore, we identify a collection of composite parameters that could potentially be measured through model fitting to assess the relative influence of accumulation versus urgency gating.

Examining Working Memory during Sentence Construction with an ACT-R Model of Grammatical Encoding

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Scarman

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We examine working memory use and incrementality using a cognitive model of grammatical encoding. Our model combines an empirically validated framework, ACT-R, with a linguistic theory, Combinatory Categorial Grammar, to target that phase of language production. By building the model with the Switchboard corpus, it can attempt to realize a larger set of sentences. With this methodology, different strategies may be compared according to the similarity of the model's sentences to the test sentences. In this way, the model can still be evaluated by its fit to human data, without overfitting to individual experiments. The results show that while having more working memory available improves performance, using less working memory during realization is correlated with a closer fit, even after controlling for sentence complexity. Further, sentences realized with a more incremental strategy are also more similar to the corpus sentences as measured by edit distance. As high incrementality is correlated with low working memory usage, this study offers a possible mechanism by which incrementality can be explained.

Virtual bargaining: A mathematical theory of social interaction

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Game theory provides a mathematical framework within which to analyse interactions between rational agents. The standard notion of the Nash equilibrium, and its many variants, provides a widely used solution concept for deriving behavioural predictions. The set of Nash equilibrium is sometimes too narrow to capture reasonable behaviour (e.g., in implicit collusion, or in the Traveller's Dilemma). It is also often too broad: the existence of multiple equilibria often makes deriving predictions difficult. We introduce an alternative notion of equilibrium, feasible agreements, which broaden the equilibrium notion, but contain all Nash equilibria. We propose that people choose a specific equilibrium through a process of mentally stimulated bargaining; the outcome of this bargaining process itself can be captured by standard mathematical models of bargaining, e.g., Nash bargaining. The resulting theory provides a formal analysis of a rich class of social and economic interactions which are puzzling within a conventional game-theoretic framework, including team coordination, implicit collusion, Traveller's Dilemma, and provides a new justification for conventional mixed strategy Nash equilibrium.

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The (simple) 2N-ary choice tree model as a model of best-worst choice

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The 2N-ary Choice Tree Model (Wollschlaeger & Diederich, 2012) is a stochastic process on a tree, which describes how preferences are constructed during the deliberation process when choosing an option from N described choice alternatives. Preferences are built on attribute weights, differences between attribute values, and noise. The model accounts for numerous context and reference point effects described in the multi-alternative multi-attribute choice literature. Here, we present a new, mathematically more tractable version of the model, the Simple Choice Tree Model. In contrast to other models for choice between multiple alternatives (e.g. MDFT, LCA, AA, MLBA), the Simple Choice Tree Model accumulates evidence for and against choosing any of the alternatives. That is, for each alternative, two evidence accumulators are established and the difference of the two accumulators is compared to a positive and a negative threshold. When the difference in evidence for a given choice option exceeds a positive threshold for the first time the option is chosen; when it exceeds a negative threshold, the choice option is rejected. Rejecting all but one of the choice alternatives is interpreted as choosing the remaining alternative. This mechanism naturally extends to situations where decision makers are asked to state the best and the worst of multiple choice options, so-called best-worst choice situations. Solutions for choice probabilities and expected response times are derived by means of birth-death chains and tridiagonal Toeplitz matrices.

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