53rd annual meeting of the society for mathematical psychology

18th international conference on cognitive modeling

conference guide

Welcome

In these unusual times I am delighted to have you join us at the first ever virtual MathPsych/ICCM conference, the joint gathering of the 53rd Annual Meeting of the Society for Mathematical Psychology (SMP) and the 18th International Conference on Cognitive Modelling (ICCM): the premier conference for research on computational models and computation-based theories of human cognition. In our joint format all sessions are open to all attendees, and cross-talk is highly encouraged.

First, I would like to express my sincere appreciation for your commitment to SMP and ICCM, and to our shared goals. While we venture into new territory with a virtual conference, it has been exciting to see the same number of submissions as we receive for our in-person conferences. This speaks to the closeness of our community and the commitment of our membership.

Second, I would like to take this opportunity to share with you some updates about SMP. As you will soon experience when uploading your presentation into the virtual conference venue, we have launched a brand new website for the society. Not only is this website an improvement on the outward facing side of SMP, but it now also allows members to log in, participate in virtual meetings, join a discussion forum, view archived presentations, search the conference schedule, and more.

Looking ahead to the future we are in the early planning stages for the 2021 MathPsych/ICCM meeting and I hope to see you in person somewhere in central Europe. We will keep you posted on this event and all other necessary information in connection with any possible adjustments to this plan. The 2021 conference will host keynote addresses by, among others, Dora Matzke and Joseph Austerweil, the winners of the 2019 William K. Estes Early Career Award. The 2020 awards will be announced at our virtual business meeting on July 31.

We have an exciting program lined up for you, including virtual social events, the professional development workshop organized by the Women of Mathematical Psychology, symposia, and awards – including the inaugural Senior Fellow award.

I am particularly thankful to our conference chair, Joachim Vandekerckhove, and Secretary/Treasurer Leslie Blaha for their tremendous efforts in these difficult times. Without them this virtual conference would not be possible.

I look forward to "seeing" you in virtual space.

Sincerely,

Pernille Hemmer
President of the Society for Mathematical Psychology

mathpsych.org

About virtual MathPsych/ICCM 2020

The 2020 edition of the annual joint meeting of the Society for Mathematical Psychology and the International Conference on Cognitive Modeling will be the first edition to take place online. For many this will be a new experience. This Conference Guide will provide conference tips as well as instructions for presenters and attendees. All attendees are recommended to read through this document before the start of the conference.

The underlying philosophy to the schedule of this virtual conference is that it is **asynchronous** and relatively **low-commitment**. It was felt by the organizing committee that attendees all over the world should be able to enjoy a virtual conference equally. Furthermore, we wanted to make it possible to participate, at least partially, even without a fast internet connection, and without the need to commit the majority of one's time.

MathPsych/ICCM 2020 is intended to be welcoming and accessible to all. It is hoped that a slow-moving, measured schedule will allow everyone to participate, regardless of geographical location, and in a way that can be combined with other responsibilities.

MathPsych

The Society for Mathematical Psychology promotes the advancement and communication of research in mathematical psychology and related disciplines. Mathematical psychology is broadly defined to include work of a theoretical character that uses mathematical methods, formal logic, or computer simulation. The official journals of the society are the *Journal of Mathematical Psychology* and *Computational Brain & Behavior*.

ICCM

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

Contents

Code of conduct

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

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

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

Enforcement

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

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

Reporting

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

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

The conference will take place primarily on virtual.mathpsych.org (the *conference venue*). Some parts of the conference are accessible only to registered participants, so you need to log in using the 'Member login' button at the top right.

The conference will be held mostly asynchronously, over a period starting on **July 20, 2020**, and concluding on **July 31, 2020**. Shortly before the beginning of this period, all prerecorded presentations will be published on the conference venue.

Venue and rooms

The venue is divided into different sections, which we are calling **rooms**. The main rooms are named after famous Renaissance artists: the *Donatello Room*, the *Leonardo Room*, the *Michelangelo Room*, and the *Raphael Room*. A dedicated room for Q&A sessions, workshops, and other live events is the *Toronto Room*. The poster session and social events will be held in the *Zen Garden*. Once you are logged in at virtual.mathpsych.org, entering a room is as easy as clicking a link at the top of the page (or tapping in a navigation menu on a mobile device).

Simultaneously released, sequentially featured presentations

While all presentations will be made available at the same time on or about **July 15, 2020**, and remain available throughout, we will publish **recommended viewing times**. Every weekday, a set of approximately 15 virtual talks will be "featured" across three or four rooms. Presentations will remain featured for two days, giving everyone in all time zones the opportunity to view them. With 10 to 15 talks being recommended each day, and each talk taking no more than 15 minutes, the time commitment to view every talk in the conference is at a maximum four hours per weekday. Eventually each talk will be featured once.

Discussion boards for constant engagement

While (and after) a presentation is featured, we encourage all conference attendees to participate in the **discussion board** to post questions about the presentation or engage in in-depth group discussions. A lengthy exchange on a public discussion board forms a potentially very useful resource for the audience's deeper understanding of a topic.

Live Q&A follow-up

A fixed period of time after a presentation is featured, selected speakers will participate as panelists in a moderated live Q&A session. In these sessions, panelists will answer questions about the work they presented as part of a Symposium or as part of a Concerted Session. Participation in a Q&A session (both as a panelist and as an audience member) is by invitation only. Panelists will be asked to kick off the Q&A session by answering selected questions from the **discussion board**.

MathPsych live Q&A sessions will be held exactly one week after the presentation is featured. ICCM live Q&A sessions will be held exactly two business days after the presentation is featured.

Live events

While much of the conference will be accessible to the public, all interactive (live) events will be tightly secured. Access to live Q&A sessions will require users to log in with a verified account. Access to all social events will be restricted to verified, registered attendees who reserved a virtual seat ahead of time. Access to the MathPsych business meeting will be restricted to current members of the Society for Mathematical Psychology.

Live events will make use of third-party services such as Zoom (zoom.us), Crowdcast (crowdcast.io), and OnlineTown (town.siempre.io). These services will be free to use and work inside a regular browser. Zoom and Crowdcast also work as apps on most smartphones; OnlineTown requires a desktop or laptop. These services all require a camera and a microphone. Access will be protected by private access links and individual passwords, which will be disseminated via the conference venue — be sure to keep an eye on the *Zen Garden* (for social events) and the *Toronto Room* (for other live events).

Finally, note that we can make no guarantees that live events will happen as planned. A lot can happen to make live events impossible without notice. In the unlikely case that an ongoing event is abruptly interrupted, check the *Zen Garden* or *Toronto Room* for updates.

Certificate of attendance

A certificate of attendance can be obtained from the conference venue. Log in to your User account and go to Profile → Certificate of Attendance.

Presenting at virtual MathPsych/ICCM 2020

The 2020 conference will be the first MathPsych/ICCM meeting to be held online. Since the mechanics of such a conference will be new to many, we have designed a small set of guidelines that all presenters should take into account. **Please read this entire chapter.**

Part of these guidelines are informed by our belief that our research should be, to the fullest extent possible, accessible to all. As a result, when authors submit a presentation to MathPsych/ICCM, we believe it should be considered **publicly accessible by default**. Submitters will be given the choice to opt out of the immediate publication of their presentation. Instead they can choose to embargo their work for any amount of time, even permanently, during which the presentation will be accessible to authenticated users only.

To learn more about embargoing or about submitting your presentation without making it public (or, more generally, without using YouTube), be sure to read the section titled "If you have concerns about publication…" on page 15.

Record your presentation

All presentations should be recorded using **screen capture software with voice-over**. This tends to produce higher quality sound and video than camera recordings of slide projections. Software to record your screen and audio is relatively easy to come by. Zoom is currently a popular option at many universities. Current versions of all major computer operating systems have built-in screen recorders that also allow for recording audio from the microphone and allow the presenter to use the mouse as one would a laser pointer. The main hardware requirement is a microphone that can be placed close to you.

When you record the voice-over, please keep in mind that there is essentially no distance between you and the audience's ear. Speak in a clear, "inside voice." Also be mindful of the international character of the audience: Just as you should avoid unnecessary jargon, it is best to avoid slang and expressions that might be unfamiliar to non-native speakers of English.

Finally, also keep in mind that your talk will be visible to a large and diverse audience, and the Code of Conduct applies here, too.

Publish your presentation

If at all possible, presentations should be uploaded to YouTube. This has a number of advantages, including free storage, high bandwidth, and automatic closed captioning. To upload a video to YouTube, you need a Google or GSuite account (many institutional email addresses are GSuite accounts; personal Google accounts are free and easy to make).

1. Go to studio.youtube.com
2. Log in with your Google or GSuite account
3. Click the CREATE button
4. Choose "Upload videos" and select your recording
5. Enter a title
6. Enter the following description:

   > This presentation is part of MathPsych/ICCM 2020.
   > See more via http://mathpsych.org/conferences/2020/.

7. Make note of the **Video link** on the right side of the window (this is what you will need to submit at the conference venue)
8. Answer the required questions (e.g., this video is not targeted at children; this video has never appeared on television)
9. When asked about privacy settings, choose either **Public** or **Unlisted**

Publishing via YouTube is currently free and allows users to upload an unlimited number of videos (videos longer than 15 minutes require account verification; but no presentation format at MathPsych/ICCM is longer than 15 minutes). Among other things, this means that presenters who have trouble using YouTube can ask any friend or colleague to upload a video to their account. If you are not able to upload a video to YouTube, you may also contact the MathPsych Conference Chair (see p. 153) who can do it on your behalf.

Closed captioning

All prerecorded videos **must** have captions available. This is an accessibility requirement of the conference. Fortunately, YouTube makes this very easy — once you upload a video, an automatic speech-to-text engine will generate closed captions for your video. They are added to your video a few minutes after uploading. While the automatically generated captions are generally good, they do need to be checked and often edited manually. To do so, take the following steps.

1. Go to studio.youtube.com
2. Log in with your Google or GSuite account
3. In the left bar menu, click "Subtitles" to see a list of videos you have uploaded
4. Click the downward arrow under "Languages," next to your presentation

5. Click the line that reads "English (automatic)" that has appeared

This will bring you to a relatively intuitive subtitle editor that allows you to edit the generated captions while listening to the audio.

Submitting your recorded presentation to the conference

All presenters at the conference should make sure they are registered as participants (see mathpsych.org/conferences/2020). Participants will be provided with separate login credentials for the conference venue (virtual.mathpsych.org). There, the details of your presentation can be found under Profile → My submissions, and the YouTube **Video link** can be added.

The deadline for submitting the recording is **July 12, 2020**. Note that the recordings will be reviewed before they are published. It is important that the instructions above as well as the specific instructions (on p. 16 and beyond) are closely followed.

Copyright information; intellectual property

Before you record

Since materials submitted to the conference will by default be made available to the public, we have to consider whose intellectual property is involved. Please make sure that everything in your recorded presentation is either in the public domain, or that it is your own intellectual property, or that you have the permission of the copyright holder to publish the material and to transfer the right to publish. In particular, if you use figures, clip art, or other audiovisual material that was previously published (by anyone, anywhere; not just an academic publisher), those may not be permitted.

When you submit the recording

At the time you submit your recording, you will be asked to give the Society for Mathematical Psychology the right to publish your presentation. Specifically, you will have to confirm the following statement:

> I hereby give the Society for Mathematical Psychology a non-exclusive, non-transferable, non-revocable license to make this content publicly available.

You will also be able to specify an embargo if you so desire.

If you have concerns about publication or about using YouTube

If you are unable or unwilling to make your recording available to the general public, or unable or unwilling to use YouTube, you may contact the MathPsych Conference Chair for instructions on how to make your presentation available to the conference attendees only. We are able to store

recordings on a private server and make them visible only to users who are logged in and who have confirmed their identity. However, please keep in mind that this confers essentially no guarantees in practice. With hundreds of people with the ability to log in, we have no practical way to contain the illicit dissemination of digital materials.

Additionally, if you choose this option, it would be your responsibility to add closed captions for your presentation.

Specific instructions for presenters

Virtual MathPsych Talk

Virtual MathPsych Talks are spoken presentations accompanied by a slide deck. The maximum duration of a Virtual MathPsych Talk presentation is **15 minutes and 0 seconds**, but shorter presentations are welcome.

Because these presentations will be published by the Society for Mathematical Psychology, we have added minor rules regarding the format and style of the presentation:

1. Talks should be recorded as screencasts, showing only slides with voiceover (not, e.g., a camera recording of a presenter and a projection).
2. The opening slide will be provided by us (see an example in Figure 1) via email.
3. Presenters should start the recording by introducing themselves by name ("Hello, my name is…") and stating that "this is a prerecorded presentation for the 2020 Meeting of the Society for Mathematical Psychology."

To submit a presentation, go to the conference venue virtual.mathpsych.org, log in, and select Profile → My submissions. You will need the YouTube **Video link**.

Virtual MathPsych Poster

The name notwithstanding, Virtual MathPsych Posters are also spoken presentations accompanied by a slide deck. The maximum duration of a Virtual MathPsych Poster presentation is **5 minutes and 0 seconds**, but shorter presentations are encouraged. Virtual MathPsych Posters should absolutely have no more than 4 slides (not including the provided title slide). The underlying idea is that this recording is the equivalent to the short pitch that poster presenters give to passers-by.

Because these presentations will be published by the Society for Mathematical Psychology, we have added minor rules regarding the format and style of the presentation:

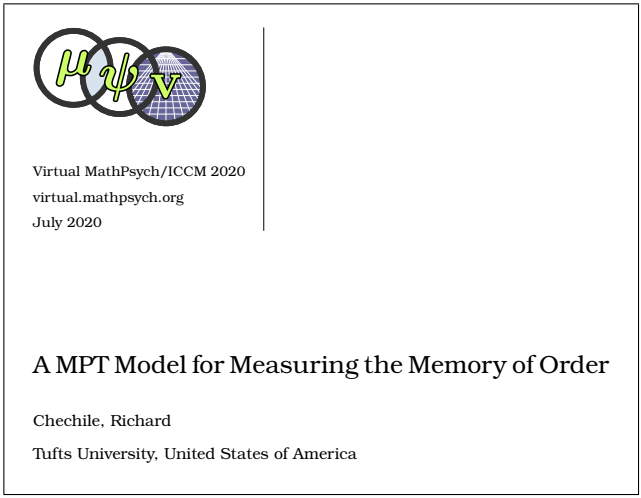

Figure 1: An example opening slide for the Virtual MathPsych Talk format.

1. Talks should be recorded as screencasts, showing only slides with voiceover (not, e.g., a camera recording of a presenter and a projection).
2. The opening slide will be provided by us (see an example in Figure 1) via email.
3. Presenters should start the recording by introducing themselves by name ("Hello, my name is…") and stating that "this is a prerecorded presentation for the 2020 Meeting of the Society for Mathematical Psychology."

An option that is perhaps slightly more challenging is for presenters to use a single slide that contains an entire poster, and then zoom in/out and pan over the poster as they narrate the presentation. This may be useful for presenters who already have a poster prepared. Note that the screen recording should still begin with the provided title slide.

To submit a presentation, go to the conference venue virtual.mathpsych.org, log in, and select Profile → My submissions. You will need the YouTube **Video link**.

Virtual ICCM Paper

Virtual ICCM Papers are spoken presentations accompanied by a slide deck. The maximum duration of a Virtual ICCM Papers presentation is **15 minutes and 0 seconds**, but shorter presentations are welcome.

Figure 2: An example opening slide for the Virtual ICCM Paper format.

Because these presentations will be published by the Society for Mathematical Psychology, we have added minor rules regarding the format and style of the presentation:

1. Talks should be recorded as screencasts, showing only slides with voiceover (not, e.g., a camera recording of a presenter and a projection).
2. The opening slide will be provided by us (see an example in Figure 2) via email.
3. Presenters should start the recording by introducing themselves by name ("Hello, my name is…") and stating that "this is a prerecorded presentation for the 2020 International Conference on Cognitive Modeling."

To submit a presentation, go to the conference venue virtual.mathpsych.org, log in, and select Profile → My submissions. You will need the YouTube **Video link**.

Virtual ICCM poster

The name notwithstanding, Virtual ICCM Posters are also spoken presentations accompanied by a slide deck. The maximum duration of a Virtual ICCM Poster presentation is **5 minutes and 0 seconds**, but shorter presentations are encouraged. Virtual ICCM Posters should absolutely have no more than 4 slides (not including the provided title slide). The underlying idea is that this recording is the equivalent to the short pitch that poster presenters

give to passers-by.

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2. The opening slide will be provided by us (see an example in Figure 2) via email.
3. Presenters should start the recording by introducing themselves by name ("Hello, my name is…") and stating that "this is a prerecorded presentation for the 2020 International Conference on Cognitive Modeling."

An option that is perhaps slightly more challenging is for presenters to use a single slide that contains an entire poster, and then zoom in/out and pan over the poster as they narrate the presentation. This may be useful for presenters who already have a poster prepared. Note that the screen recording should still begin with the provided title slide.

To submit a presentation, go to the conference venue virtual.mathpsych.org, log in, and select Profile → My submissions. You will need the YouTube **Video link**.

Live Q&A instructions

Symposium speakers and speakers in **concerted sessions** will be invited to participate in a live Q&A session one week after the session is featured (see page 37 for dates and times).

In these sessions, panelists will answer questions about the work they presented as part of a Symposium or as part of a Concerted Session. Panelists will be asked to kick off the Q&A session by answering selected questions from the **discussion board**. Each panelist will also be asked to introduce themselves and provide the audience with a short (1-2 minute) refresher on the topic of their presentation.

Q&A sessions will be moderated by one or two conference staff members and will be accessible only to authenticated users. They will not be live-streamed in any public venue. After the session, a recording of a Q&A session will be made public only if all panelists in that session give their permission.

A note on timing of the live Q&A sessions

All MathPsych live sessions are scheduled from 4:00pm to 5:00pm or from 5:00pm to 6:00pm, Eastern Daylight Time. We are aware that this is not an ideal time for all presenters and audience members. The decision to hold live sessions in this time slot is based on a combination of considerations: That the majority of presenters (and therefore the likely majority of the audience) at the conference are in North America (57%); That the selected time slot is merely in the evening (rather than in the middle of the night) in Central European Summer Time and in the early morning in Australian Eastern Standard Time, which together account for the majority of the remaining presenters (34%); and that our tech support is based in the overlapping Atlantic Standard Time zone.

By similar reasoning, the ICCM live sessions will be held from 12:00 noon to 1:00pm, Eastern Daylight Time. ICCM's membership leans more toward Europe than to Australia by a significant margin.

CS: Concerted Session, CT: Contributed Talk, SY: Symposium

July 20 — 21

Room	Group Dynamics		
Donatello	CS	**Lee, Michael David** University of California, Irvine	Model-based wisdom of the crowd for sequential decisions
Donatello	CS	**Davis, Alex** Carnegie Mellon University	Public policy recommendation by optimizing an unknown social welfare function
Donatello	CS	**Bennett, Murray** University of Newcastle	An iterated prospect theory model for the Dutch auction
Donatello	CS	**Ransom, Keith** University of Melbourne	The polarising effect of epistemic vigilance in populations of Bayesian agents

Room	Optimal Experimental Design		
Leonardo	SY	**Myung, Jay I.** Ohio State University	An introduction to optimal experimental design
Leonardo	SY	**Goodman, Noah** Stanford University	Automating experiments with neural information estimators
Leonardo	SY	**Lorenz, Romy** University of Cambridge	Neuroadaptive Bayesian optimization for cognitive neuroscientists
Leonardo	SY	**Melinscak, Filip** Psychiatric Hospital, U. Zurich	Optimizing associative learning experiments
Leonardo	SY	**Bak, Ji Hyun** University of California, Berkeley	Dynamic tracking and adaptive optimal training of decision-making behavior
Leonardo	SY	**Ahn, Woo-Young** Seoul National University	Toward rapid, precise, and reliable computational markers of addictive behaviors using adaptive design optimization and digital phenotyping
Leonardo	SY	**Lu, Zhong-Lin** New York University	The contrast sensitivity function: From laboratory to clinic
Leonardo	SY	**Suchow, Jordan W.** Stevens Institute of Technology	Active experiment design in crowdsourced experiments

Day 2 | MathPsych Viewing Schedule

July 21 — 22

Room	Systems and Architectures		
Donatello	CS	**Howard, Zachary** University of Western Australia	Nice guys check twice — Questioning the assumptions of the capacity coefficient
Donatello	CS	**Eidels, Ami** University of Newcastle	Investigating the processing architecture in memory intersection problems
Donatello	CS	**Church, Kinsey Antonina** University of Ottawa	Using context to shift from line to point attractors in a bidirectional associative memory
Donatello	CS	**Brady, Timothy** University of California, San Diego	No distinction between 'capacity' and 'precision': Populations of noisy familiarity signals explain visual memory errors
Donatello	CS	**Fox, Elizabeth** Air Force Research Labs	A Bayesian Model of capacity across time
Donatello	CS	**Ballard, Timothy** The University of Queensland	A general architecture for modeling the dynamics of goal-directed motivation and decision making
Donatello	CS	**Langenfeld, Vincent** University of Freiburg	A framework for the formal operational description of ACT-R.

Room	Symposium: Computational Model-Based Cognitive Neuroscience		
Leonardo	SY	**Mistry, Percy** Stanford University	Combining hierarchical latent-mixture and evidence accumulation-based models with fMRI data
Leonardo	SY	**Liu, Qingfang** The Ohio State University	Extensions of multivariate dynamical systems to simultaneously explain neural and behavioral data
Leonardo	SY	**Supekar, Kaustubh** Stanford University	Hidden Markov model approaches and Bayesian methods to investigate brain dynamics and cognitive-state switching in children
Leonardo	SY	**Turner, Brandon** The Ohio State University	Linking functions for mind, brain and behavior

July 22 — 23

Room	Cognitive Neuromodeling		
Donatello	CS	**Nunez, Michael D.** University of California, Los Angeles	Understanding individual differences in Rhesus macaques' strategies for visual evidence accumulation
Donatello	CS	**Fontanesi, Laura** University of Basel	Single-trial estimates of sequential sampling models parameters are not just noisy but can also be biased
Donatello	CS	**Weindel, Gabriel** Aix-Marseille Université	Assessing model-based inferences in decision making with single-trial response time decomposition
Donatello	CS	**Hays, Jason** Florida International University	Changes within neural population codes can be inferred from psychophysical threshold studies
Donatello	CS	**Manning, Catherine** University of Oxford	Perceptual decision-making in children: Age-related differences and EEG correlates

Room	Symposium: Theory Development		
Leonardo	SY	**Guest, Olivia** University College London **Martin, Andrea E.** Max Planck Institute for Psycholinguistics	How computational modeling can force theory building in psychological science
Leonardo	SY	**Donkin, Chris** University of New South Wales	Clarifying the role of mathematics in theory development
Leonardo	SY	**Perfors, Amy** University of Melbourne	Generating theories are hard, and none of our theories are good enough
Leonardo	SY	**Van Rooij, Iris** Radboud University	Good theories are possible
Leonardo	SY	**Varma, Sashank** University of Minnesota Duluth	Theories that explain versus theories that describe: the case of constraint satisfaction
Leonardo	SY	**Kellen, David** Syracuse University	Theories as modelling ecologies

Day 4 | MathPsych Viewing Schedule

July 23 — 24

Room	Learning		
Donatello	CS	**Brockbank, Erik** University of California, San Diego	Adaptive reasoning in rock-paper-scissors
Donatello	CS	**Fang, Zeming** Rensselaer Polytechnic Institute	A rate-distortion theory analysis of human bounded rational learning
Donatello	CS	**Baribault, Beth** University of California, Berkeley	Differences in learning process dynamics when rewards are familiar versus instructed
Donatello	CS	**Doh, Hoyoung** Seoul National University	Dissecting the mechanism of Pavlovian bias with the orthogonalized Approach/Withdrawal task and mouse-tracking
Donatello	CS	**McCormick, Erin** Carnegie Mellon University	Analyzing variability in instance-based learning model predictions using recurrence quantification analysis

Room	Optimality in Choice		
Michelangelo	CS	**Dunn, John** University of Western Australia	A model of target position effects in a sequential lineup.
Michelangelo	CS	**Kraemer, Peter Maximilian** University of Basel	Response time models separate single- and dual-process accounts of memory-based decisions
Michelangelo	CS	**Cruz, Nicole** University of New South Wales	Single vs. dual process theories of reasoning in a Bayesian signal detection theory framework
Michelangelo	CS	**He, Lisheng** University of Pennsylvania	A solution to the feature binding problem for risky choice
Michelangelo	CS	**Haines, Nathaniel** The Ohio State University	Anxiety modulates preference for immediate rewards among trait-impulsive individuals: a decision theory and hierarchical Bayesian analysis

July 24 — 25

Room	Joint Modeling		
Donatello	CS	**Bahg, Giwon** The Ohio State University	Gaussian process joint models for estimating latent dynamics of brain and behavior
Donatello	CS	**Steyvers, Mark** University of California, Irvine	Inferring latent learning factors in large-scale cognitive training data
Donatello	CS	**Galdo, Matthew** The Ohio State University	Towards a quantitative framework for detecting transfer of learning
Donatello	CS	**Gluth, Sebastian** University of Basel	Joint modeling of choices, response times, and eye movements
Donatello	CS	**Klevjer, Kristoffer** UiT The Arctic University of Norway	Bayesian analysis of risk- and ambiguity aversion in two information sampling tasks

Room	Psychometrics		
Michelangelo	CS	**Chechile, Richard** Tufts University	A MPT model for measuring the memory of order
Michelangelo	CS	**Perquin, Marlou Nadine** Cardiff University	Temporal structures in sensorimotor variability are reliable… but what for?
Michelangelo	CS	**Malejka, Simone** University College London	Two Bayesian corrections for attenuation in correlation analysis to investigate unconscious mental processes
Michelangelo	CS	**Cosyn, Eric** McGraw-Hill Education	A practical perspective on knowledge space theory: ALEKS and its data
Michelangelo	CS	**Krefeld-Schwalb, Antonia** Columbia University	Structural parameter interdependencies in computational models of cognition

Day 6 | MathPsych Viewing Schedule

July 27 — 28

Room	Categorization		
Donatello	CT	**Bhui, Rahul** Harvard University	Attention constraints and learning in categories
Donatello	CT	**Sanborn, Adam** University of Warwick	REFRESH: A new approach to modeling dimensional biases in perceptual similarity and categorization
Donatello	CT	**Soto, Fabian** Florida International University	An observer model version of general recognition theory
Donatello	CT	**Wimsatt, Jay** Ohio University	Contrast as supervision in process models of classification behavior

Room	Memory		
Leonardo	CT	**Dennis, Simon** University of Melbourne	Understanding memory for WHERE using smartphone sata
Leonardo	CT	**Zhang, Qiong** Princeton University	The method of loci is an optimal policy for memory search
Leonardo	CT	**Cao, Kesong** University of Wisconsin-Madison	How does modern life affect memory retrieval: analyzing news headlines
Leonardo	CT	**Shabahang, Kevin** University of Melbourne	Beyond pattern completion with short-term plasticity

Room	Decision Making		
Michelangelo	CT	**Kane, Patrick Bodilly** McGill University	Applications of the bias-variance decomposition to human forecasting
Michelangelo	CT	**Kvam, Peter** University of Florida	Constraints on continuous models applied to binary and multi-alternative choice
Michelangelo	CT	**Montero, Milton Llera** University of Bristol	Deep generative models as perceptual front-ends for decision-making
Michelangelo	CT	**Chang, Jorge** The Ohio State University	Data-driven modeling of delay discounting identifies novel discounting behavior

July 28 — 29

Room	Memory Research Methods		
Donatello	CT	**Van der Velde, Maarten** University of Groningen	A Bayesian collaborative filtering approach to alleviating the Cold Start Problem in adaptive fact learning
Donatello	CT	**Lange, Nicholas** University of Warwick	Using cross-validation to evaluate model components: The case of visual working memory
Donatello	CT	**Lerch, Rachel** Rensselaer Polytechnic Institute	Effects of working memory load on motor force learning: a computational account
Donatello	CT	**Westfall, Holly** University of California, Irvine	Using neural-network classification accuracy to measure the sufficiency of inferred cognitive parameters

Room	Recognition Memory		
Leonardo	CT	**Yim, Hyungwook** The University of Melbourne	A systematic re-examination of the list-length effect in recognition memory
Leonardo	CT	**Fox, Julian William** The University of Melbourne	Does source memory exist for unrecognized items?
Leonardo	CT	**Glavan, Joseph** Wright State University	Adaptive design for general recognition theory experiments
Leonardo	CT	**Osth, Adam** The University of Melbourne	Integrating word-form representations with global similarity computation in recognition memory

Room	Metascience		
Michelangelo	CT	**Morís Fernández, Luis** Autonomous U. of Madrid	Flexibility in reaction time analysis: Many roads to a false positive?
Michelangelo	CT	**Morís, Joaquín** Autonomous U. of Madrid	Type I error in diffusion models: A drift towards false positives?
Michelangelo	CT	**Vigo, Ronaldo** Ohio University	Foundational challenges for mathematical and computational cognitive modeling in the 21st Century
Michelangelo	CT	**Brandtzæg, Ørjan R.** Norwegian U. of Sci. & Tech.	On bias, signal detection, and sequential sampling
Michelangelo	CT	**Lisøy, Rebekka Solvik** Norwegian U. of Sci. & Tech.	Prediction error and surprise

Day 8 | MathPsych Viewing Schedule

July 29 — 30

Room	Judgment		
Donatello	CT	**Desai, Nitisha** The Ohio State University	Decomposing categorical and item-specific preferences using sequential sampling models
Donatello	CT	**Yi, Woojong** The Ohio State University	Confidence as a continuous state of evidence with dynamic competition
Donatello	CT	**Yang, Xiaozhi** The Ohio State University	Attentional dynamics in multi-attribute preferential choices
Donatello	CT	**Krajbich, Ian** The Ohio State University	Explicit value cues and response caution in value-based decisions
Donatello	CT	**Schramm, Pele** Technion, Israel Institute of Technology	To maximize gains or to minimize losses?

Room	Statistics		
Michelangelo	CT	**Sloman, Sabina Johanna** Carnegie Mellon University	Using parameter contours to achieve more robust model estimation
Michelangelo	CT	**Chen, Yiyang** The Ohio State University	A hierarchical Bayesian model for the progressive ratio test
Michelangelo	CT	**Katsimpokis, Dimitris** University of Basel	A robust Bayesian test for context effects in multi-attribute decision making
Michelangelo	CT	**Singmann, Henrik** University of Warwick	stanova: user-friendly interface and summaries for Bayesian statistical models estimated with Stan
Michelangelo	CT	**Villarreal, Jesus Manuel** University of California, Irvine	Prior predictive entropy as a measure of model complexity
Michelangelo	CT	**Shiffrin, Richard** Indiana University	Lord's Paradox: Why science should govern statistics, not the reverse
Michelangelo	CT	**Rouder, Jeffrey** University of California, Irvine	How useful is posterior-predictive model assessment: Insights from ordinal constraints

July 30 — 31

Room	Reaction Time Analysis		
Donatello	CT	**Gondan, Matthias** University of Copenhagen	Testing the race model in a difficult redundant signals task
Donatello	CT	**Lerche, Veronika** Heidelberg University	Effects of frustration of the achievement motive on task processing: Findings from diffusion model analyses
Donatello	CT	**Otto, Thomas U.** University of St. Andrews	The associative property holds for combination of auditory, visual, and tactile signals in multisensory decisions
Donatello	CT	**Bompas, Aline** Cardiff University	Estimating non-decision time in visuo-saccadic response time
Donatello	CT	**Shevlin, Blair** The Ohio State University	Attention as a source of overall value effects in diffusion models

Room	Reaction Time Models		
Michelangelo	CT	**Zhou, Jason** University of Melbourne	A circular diffusion model of continuous-outcome source memory retrieval
Michelangelo	CT	**Hawkins, Guy** University of Newcastle	The timed racing diffusion model of decision making
Michelangelo	CT	**Bunji, Kyosuke** Benesse Educational Research and Development Institute	An extension of the LBA-IRT model to multidimensional multiple-alternative forced-choice personality measurement with response times
Michelangelo	CT	**Salet, Josh Manu** University of Groningen	fMTP: a unifying computational framework of temporal preparation across time scales
Michelangelo	CT	**Baker, Sophie-Anne** University of Bristol	Degenerate optimal boundaries for multiple-alternative decision making
Michelangelo	CT	**Gasaneo, Gustavo** Universidad Nacional del Sur, Argentina	The Trail Making Test: a simple model based on an eye-tracking study

Day 10 | MathPsych Viewing Schedule

July 31 — August 1

Room	Applied MathPsych		
Donatello	CT	**Romeu, Ricardo Jose** Indiana University Bloomington	An application of a hierarchical diffusion model on ambulatory data from Huntington's patients
Donatello	CT	**Hatz, Laura** University of Missouri	Acute alcohol effects on risky sexual decision making
Donatello	CT	**Yang, Jaeyeong** Seoul National University	Identifying computational markers of future nicotine intake using adaptive design optimization in a smartphone app
Donatello	CT	**Pfuhl, Gerit** UiT The Arctic University of Norway	Who's more Bayesian? Belief updating and no conservatism bias in Schizophrenia
Donatello	CT	**Sims, Chris** Rensselaer Polytechnic Institute	Bayesian hierarchical estimation of visual change detection using Gaussian Markov Random Field priors
Donatello	CT	**Han, Qing** University of Bristol	How does risk perception of COVID-19 influence emotion and mental health during the pandemic: A specification curve analysis

Room	Axiomatics and Formal Analysis		
Michelangelo	CT	**Doble, Christopher** McGraw-Hill Education	On the functional forms in a psychophysical law of similarity under a subtractive representation
Michelangelo	CT	**Zhang, Jun** University of Michigan	Information geometry and statistical mirror symmetry
Michelangelo	CT	**Bamber, Donald** University of California, Irvine	A new axiomatization of Luce's model of choice and ranking
Michelangelo	CT	**Dzhafarov, Ehtibar** Purdue University	Contextuality as an extension of selective influences
Michelangelo	CT	**Cervantes Botero, Víctor Hernando** Purdue University	Detecting contextuality in systems with categorical variables
Michelangelo	CT	**Akrenius, Mikaela** Indiana University	Applications of information theory to perceptual independence and separability

CS: Concerted Session, CT: Contributed Talk, SY: Symposium

July 20 — 21

Room	ICCM Session I		
Raphael	CS	**Radev, Stefan** Heidelberg University	Amortized Bayesian Inference for Models of Cognition
Raphael	CS	**Caron, Emilie Elizabeth** University of Waterloo	A Distributed Spiking Neuron Model of Attention in the Stroop Task
Raphael	CS	**Martinez Rodriguez, L. Alexandra** University College Dublin	Neurally-informed modelling of static and dynamic decision biases
Raphael	CS	**Cranford, Edward Andrew** Carnegie Mellon University	Cognitive Saliency of Features in Cyber-attacker Decision Making
Raphael	CS	**Stöckel, Andreas** University of Waterloo	Connecting Biological Detail with Neural Computation: Application to the Cerebellar Granule-Golgi Microcircuit

Day 2 | ICCM Viewing Schedule

July 21 — 22

Room	ICCM Session II		
Raphael	CS	**Salvucci, Dario D.** Drexel University	Interactive Grounding and Inference in Instruction Following
Raphael	CS	**Veksler, Bella** Tier1 Performance Solutions	Integrated Model of Fatigue and C-17 Approach and Landing Operations
Raphael	CS	**Sibert, Catherine** University of Washington	The Need for Speed: Effects of Human Derived Time Constraints on Performance and Strategy in Machine Models of Tetris
Raphael	CS	**Blaha, Leslie** Air Force Research Laboratory	Cognitive Mechanisms for Calibrating Trust and Reliance on Automation
Raphael	CS	**Somers, Sterling** Carnegie Mellon University	Cognitive Twin: A Cognitive Approach to Personalized Assistants

July 22 — 23

Room	ICCM Session III		
Raphael	CS	**Gianferrara, Pierre Giovanni** Carnegie Mellon University	Time-related Effects of Speed on Motor Skill Acquisition
Raphael	CS	**Nagashima, Kazuma** Shizuoka University	Modeling intrinsic motivation in ACT-R: Focusing on the relation between pattern matching and intellectual curiosity
Raphael	CS	**Harrison, Anthony** US Naval Research Laboratory	An Imperative Alternative to Productions for ACT-R
Raphael	CS	**Collins, Michael** Cognitive Models and Agents Branch	Detecting Learning Phases to Improve Performance Prediction

Day 4 | ICCM Viewing Schedule

July 23 — 24

Room	ICCM Session IV		
Raphael	CS	**Brasoveanu, Adrian** UC Santa Cruz	Reinforcement Learning for Production-based Cognitive Models
Raphael	CS	**Ragni, Marco** University Freiburg	The Power of Nonmonotonic Logics to Predict the Individual Reasoner
Raphael	CS	**Nguyen, Thuy Ngoc** Carnegie Mellon University	Effects of Decision Complexity in Goal-seeking Gridworlds: A Comparison of Instance-Based Learning and Reinforcement Learning Agents
Raphael	CS	**Akrenius, Mikaela** Indiana University	Information Theory Meets Expected Utility: The Entropic Roots of Probability Weighting Functions
Raphael	CS	**Haile, Theodros** University of Washington	One Size Doesn't Fit All: Idiographic Computational Models Reveal Individual Differences in Learning and Meta-Learning Strategies

July 24 — 25

Room	ICCM Session V		
Raphael	CS	**Khoe, Yung Han** Radboud University Nijmegen	Modeling cross-language structural priming in sentence production
Raphael	CS	**Wenzl, Petra** University of Bremen	What Everyday Activities Reveal About Spatial Representation and Planning Depth
Raphael	CS	**Tenison, Caitlin** Educational Testing Service	Characterizing Pause Behaviors in a Science Inquiry Task
Raphael	CS	**Smith, Briana Marie** University of Washington	Modeling the Effects of Post-Traumatic Stress on Hippocampal Volume
Raphael	CS	**Jones, Stephen Mark** University of Groningen	A grammatically robust cognitive mode of English and Korean sentence processing

Q&A sessions

All Q&A events will be coordinated via the *Toronto Room*. All times are in EDT (UTC −4). All live events are subject to change.

Room	Session		
Wed, July 22	Q&A	**12:00 PM — 1:00 PM**	ICCM Session I Q&A
Thu, July 23	Q&A	**12:00 PM — 1:00 PM**	ICCM Session II Q&A
Fri, July 24	Q&A	**12:00 PM — 1:00 PM**	ICCM Session III Q&A
Mon, July 27	Q&A	**12:00 PM — 1:00 PM**	ICCM Session IV Q&A
Mon, July 27	Q&A	**4:00 PM — 5:00 PM**	Group Dynamics Q&A
Mon, July 27	Q&A	**5:00 PM — 6:00 PM**	Optimal Experimental Design Q&A
Tue, July 28	Q&A	**12:00 PM — 1:00 PM**	ICCM Session V Q&A
Tue, July 28	Q&A	**4:00 PM — 5:00 PM**	Systems and Architectures Q&A
Tue, July 28	Q&A	**5:00 PM — 6:00 PM**	Computational Model-Based Cognitive Neuroscience Q&A
Wed, July 29	Q&A	**4:00 PM — 5:00 PM**	Cognitive Neuromodeling Q&A

Wed, July 29	Q&A	**5:00 PM — 6:00 PM**	Theory Development Q&A
Thu, July 30	Q&A	**4:00 PM — 5:00 PM**	Learning Q&A
Thu, July 30	Q&A	**5:00 PM — 6:00 PM**	Optimality in Choice Q&A
Fri, July 31	Q&A	**4:00 PM — 5:00 PM**	Joint Modeling Q&A
Fri, July 31	Q&A	**5:00 PM — 6:00 PM**	Psychometrics Q&A

Workshops and social events

All workshops and social events will be coordinated in the *Toronto Room*. All times are in EDT (UTC −4). All live events are subject to change.

Workshops

Room	Session		
Mon, July 20	WS	**2:30 PM — 4:00 PM**	Surviving and thriving during COVID-19 (Women of MathPsych)
Sat, July 25	WS	**9:00 AM — 6:00 PM**	ACT-R Workshop
Sat, Aug 1	WS	**3:30 PM — 4:00 PM**	Being better allies (Women of MathPsych)

Social events

Room	Session		
Mon, July 20	Soc	**4:00 PM — 7:00 PM**	Welcome reception
Thu, July 23	Soc	**4:00 PM — 7:00 PM**	Graduate student and postdoc social
Wed, July 29	Soc	**6:00 PM — 7:00 PM**	Virtual banquet
Fri, July 31	Soc	**6:00 PM — 7:00 PM**	Business meeting

Group Dynamics

Model-based wisdom of the crowd for sequential decisions

CS

Lee, Michael David; Coon, Jeff; Thomas, Bobby; Westfall, Holly Anne

University of California, Irvine

We use cognitive models to apply the wisdom of the crowd to three sequential decision making problems: bandit problems, optimal stopping problems, and the Balloon Analogue Risk Task (BART). In each of these problems, people make a sequence of choices under uncertainty, with individual differences in decision making that depend on different attitudes toward risk. Each of the problems also has a known optimal decision-making strategy. Standard methods for the wisdom of the crowd, based on taking the modal behavior, are generally not applicable to these problems, because of their sequential nature. For example, the state-space of a bandit problem can be so large that, even for a large crowd of people, there will be game states that no individual encountered, and so there is no behavior to aggregate. We solve this problem using cognitive models, and inferring individual-level parameter values that predict what each individual would do for each sequential decision. The mode of these model-based predicted decisions then defines a crowd decision whose performance can be compared to individual and optimal performance.

Public policy recommendation by optimizing an unknown social welfare function

CS

Davis, Alex (1); Guo, Niles (1); Mauter, Meagan (2)

1: Carnegie Mellon University; 2: Stanford University

A classical utilitarian perspective on public decision-making is that the public should choose an alternative that maximizes some function over the utilities of individuals, called a social welfare function. If the utility function for each decision-maker is cardinal and comparable with other decision-makers, then there are many valid social welfare functions. We examine the problem of finding a social welfare function that implicitly best fits society's values, where we assume that a group's decision problem is the same as maximizing an unknown social welfare function implicitly held by the group. While there is a wealth of literature on possible social welfare functional forms based on different assumptions about the preferences of individuals, we propose a new empirical approach that approximates a group's social welfare function based on both individual preferences and group voting behavior. We test the approach's ability to promote compromise on climate-related energy policy among Pittsburgh residents who are plan to vote in the 2020 Democratic

Primary. Our three-stage research design first elicits individual preferences, then uses a mean-variance algorithm to approximate a welfare function that fits group voting behavior, then finally makes a recommendation for the group based on that function. In addition to testing whether a group's social welfare function can be learned from individual choices, this study provides a roadmap for solving group recommendation problems more broadly.

An Iterated Prospect Theory Model for the Dutch Auction

CS

Bennett, Murray; Mullard, Rachel; Brown, Scott; Eidels, Ami

University of Newcastle

Dutch auctions are used in many industries. Goods are initially offered at a high price, which is gradually lowered until the first bidder accepts it. Bidders trade certainty and price: early bids secure the sale, but overpay; later bids are cheaper, but risk losing out to another bidder. We used group-based laboratory experiments to investigate decision-making in Dutch auctions. We developed a model for bidding in Dutch auctions, based on a dynamic extension of Prospect Theory. At each moment of the auction, the buyer is faced with a decision that can be framed as classical Prospect Theory: a certain option (buy now!) or a risky option (wait a little longer for the price to fall, and hope that no-one else buys before then). We show that this model reproduces the basic phenomena of the task, and also provides a useful framework for investigating interesting questions about auction psychology. We also discuss extensions to data from real Dutch auctions.

The polarising effect of epistemic vigilance in populations of Bayesian agents

CS

Ransom, Keith; Perfors, Amy

University of Melbourne

While seeing may be believing for reasoners with access to ground truth data, reasoning from information provided by others can be considerably more complicated. Epistemic vigilance is often called for. Previous work (Perfors and Navarro, 2019) has simulated populations of Bayesian agents to demonstrate how echo chambers may emerge (where groups of agents come to distrust each other and no longer communicate), even when all agents are constrained to be truthful and fully Bayesian. The simulations showed that if agents track the epistemic trust of others over time and provided beliefs are sufficiently heterogeneous at the outset, then polarisation is somewhat inevitable. The present work broadens these results, suggesting that polarisation is a robust outcome that emerges under a wide set of assumptions about the goals and cognitive abilities of the agents. In particular, we show that similar patterns of belief clustering emerge where information sources are largely anonymous and direct source tracking is not possible. We sketch directions for future work exploring how social media architectures may affect these dynamics.

Optimal Experimental Design

An Introduction to Optimal Experimental Design

SY

Myung, Jay I.; Pitt, Mark A.

Ohio State University

Progress in science depends on well-designed experiments, yet when it comes to testing computational models, good design can be elusive because model similarities and differences are difficult to assess. Further, observations can be expensive and time-consuming to acquire (e.g., fMRI scans, children, clinical populations). 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. In addressing this challenge, statisticians have developed optimal experimental design (OED) methods that combine the power of statistical computing techniques with the predictive precision of the formal models, yielding experiments that are highly efficient and maximally informative with respect to a given experimental objective. This presentation provides an overview of OED with an emphasis on recent developments and applications in the behavioral sciences.

Automating experiments with neural information estimators

SY

Goodman, Noah

Stanford University

The idea that good experiments maximize information gain has a long history (e.g. Lindley, 1956). A key obstacle to using this insight to automate experiment design has been the difficulty of estimating information gain. In the last few years new methods have become available for casting information estimation as an optimization problem. Using these ideas, we describe variational bounds on expected information gain. Deep neural networks and gradient-based optimization then allow efficient optimization of these bounds even for complex data models. We apply these ideas to experiment design, adaptive surveys, and computer adaptive testing.

Neuroadaptive Bayesian optimization for cognitive neuroscientists

SY

Lorenz, Romy (1,2)

1: University of Cambridge, UK; 2: Stanford University, US

Cognitive neuroscientists are often interested in broad research questions, yet use overly narrow experimental designs by considering only a small subset of possible experimental conditions. This limits the generalizability and reproducibility of many research findings. In this talk, I present an alternative approach that resolves these problems by combining real-time functional magnetic resonance imaging (fMRI) with a branch of machine learning, Bayesian optimization. Neuroadaptive Bayesian

optimization is a non-parametric active sampling approach using Gaussian process regression. The approach allows to intelligently search through large experiment spaces with the aim to optimize a human subject's brain response. It thus provides a powerful strategy to efficiently explore many more experimental conditions than is currently possible with standard neuroimaging methodology. In this talk, I will present results from three different studies where we applied the method to: (1) better understand the functional role of frontoparietal networks in healthy individuals, (2) map cognitive dysfunction in aphasic stroke patients, and (3) tailor non-invasive brain stimulation parameters to a particular research question. I will conclude my talk in discussing how Bayesian optimization can be combined with study preregistration to cover exploration, mitigating researcher bias more broadly and improving reproducibility.

Optimizing associative learning experiments

SY

Melinscak, Filip (1); Bach, Dominik R. (1,2)

1: University of Zurich; 2: University College London

Understanding associative learning - the ability to acquire knowledge about contingencies between stimuli, responses, and outcomes - is crucial in explaining how animals adapt to their environments. Moreover, the theory of associative learning also provides a rationale for clinical treatments, such as exposure therapy for phobias. The study of associative learning has been significantly advanced through reliance on formal psychological modeling. However, the rich history of modeling, and the resulting abundance of models, lead to challenges in designing informative experiments. With a growing space of increasingly flexible candidate models, it is difficult to manually design experiments which efficiently discriminate between them. Here we propose to address this challenge through formal optimization of experimental designs. We first consider the structure of classical conditioning experimental designs and propose low-dimensional formalizations amenable to optimization. Next, we combine simulation-based evaluation of design utility with Bayesian optimization to efficiently search the experiment space for utility-maximizing designs. Lastly, we describe several simulated scenarios which show that optimized designs can substantially outperform canonical manual designs, whether the goal is model comparison or parameter estimation. Based on these results, we sketch out possible future avenues for optimal experimental design in associative learning, and cognitive science more broadly.

Dynamic tracking and adaptive optimal training of decision-making behavior

SY

Bak, Ji Hyun

Redwood Center for Theoretical Neuroscience, UC Berkeley

While animal training is an essential part of modern psychology experiments, the training protocol is usually hand-designed, relying heavily on trainer intuition and guesswork. I will present a general framework that takes animal training to a quan-

titative problem, building on ideas from reinforcement learning and optimal experimental design. Our work addresses two interesting problems at once: First, we develop an efficient method to characterize an animal's behavioral dynamics during learning, and infer the learning rules underlying its behavioral changes. Second, we formulate a theory for optimal training, which involves selecting sequences of stimuli that will drive the animal's internal policy toward a desired state in the parameter space according to the inferred learning rules.

Toward rapid, precise, and reliable computational markers of addictive behaviors using adaptive design optimization and digital phenotyping

SY

Ahn, Woo-Young (1); Yang, Jaeyeong (2); Pitt, Mark A. (3); Myung, Jay I. (4)

1: Department of Psychology, Seoul National University; 2: Department of Psychology, Seoul National University; 3: Department of Psychology, The Ohio State University; 4: Department of Psychology, The Ohio State University

Machine learning has the potential to facilitate the development of computational methods that improve the measurement of cognitive and mental functioning, and adaptive design optimization (ADO) is a promising machine-learning method that might lead to rapid, precise, and reliable markers of individual differences. In this talk, we will present a series of studies that utilized ADO in the area of decision-making and for the development of ADO-based digital phenotypes for addictive behaviors. Lastly, we will introduce an open-source Python package, ADOpy, which we developed to increase the accessibility of ADO to even researchers who have limited background in Bayesian statistics or cognitive modeling.

The Contrast Sensitivity Function: From Laboratory to Clinic

SY

Lu, Zhong-Lin

NYU Shanghai, New York University

The contrast sensitivity function (CSF), which describes visual sensitivity (1/contrast threshold) to narrow-band stimuli of different spatial frequencies, provides a comprehensive measure of the visual system over a wide range of spatial frequencies in both normal and abnormal vision. The CSF is closely related to daily visual functions and has proved important in characterizing functional deficits in many visual disorders. More importantly, assessment of CSF may reveal the "hidden vision loss", that is, even when acuity appears normal, patients may have evident CSF deficits. I will discuss three lines of research: (1) Modeling: Using the external noise paradigm and the perceptual template model (PTM), we characterized the CSF in terms of the gain profile, nonlinearity, additive noise, and multiplicative noise of the perceptual system. (2) Efficient Assessment: Despite the importance of assessing the CSF, the testing time needed for precise assessment has prevented its clinical application. We developed the qCSF method, a novel Bayesian adaptive psychophysical method, that can be used to provide an accurate assessment of the full CSF in a few minutes. In addition, we have conducted a number of studies to improve and validate the

method, and assess its precision, accuracy, specificity, and sensitivity. (3) Clinical Applications: The qCSF method has used in clinical settings and clinical trials to reveal hidden vision loss in a number of patient populations. I will provide a few example applications.

Active experiment design in crowdsourced experiments

Suchow, Jordan W.

Stevens Institute of Technology

As experimentation in the behavioral and social sciences moves from brick-and-mortar laboratories to the web, new opportunities arise in the design of experiments. By taking advantage of the new medium, experimenters can write complex computationally mediated adaptive procedures for gathering data: algorithms. Here, we explore the consequences of adopting an algorithmic approach to experiment design. We review several active experiment designs, describing their interpretation as algorithms. We then discuss software platforms for the efficient execution of these algorithms with people. Finally, we consider how machine learning can optimize crowdsourced experiments and form the foundation of next-generation experiment design.

Systems and Architectures

Nice Guys Check Twice — Questioning the assumptions of the capacity coefficient

Howard, Zachary (1); Garrett, Paul (2); Little, Daniel (2); Eidels, Ami (3); Townsend, James (4)

1: University of Western Australia; 2: University of Melbourne; 3: University of Newcastle; 4: Indiana University

Systems Factorial Technology (SFT) is a popular framework for that has been used to investigate processing capacity across many psychological domains over the past 25+ years. To date, it had been assumed that no processing resources are used for sources in which no signal has been presented (i.e., in a location that can contain a signal but does not on a given trial). Hence, response times are purely driven by the "signal-containing" location or locations. This assumption is critical to the underlying mathematics of the capacity coefficient measure of SFT. In this presentation, we show that stimulus locations influence response times even when they contain no signal, and that this influence has repercussions for the interpretation of processing capacity under the SFT framework, particularly in conjunctive (AND) tasks - where positive responses require detection of signals in multiple locations. We propose a modification to the AND task requiring participants to fully identify both target locations on all trials. This modification allows a new coefficient to be derived. We apply the new coefficient to novel experimental data and resolve a

previously reported empirical paradox, where observed capacity was limited in an OR detection task but super capacity in an AND detection task. Hence, previously reported differences in processing capacity between OR and AND task designs are likely to have been spurious.

Investigating the Processing Architecture in Memory Intersection Problems

CS

Howard, Zachary (1); Eidels, Ami (1); Belevski, Bianca (1); Dennis, Simon (2)

1: University of Newcastle; 2: University of Melbourne

Cues can be used to improve performance on memory recall tasks, and additional cues provide further benefit, presumably by narrowing the search space. Problems that require integration of two or more cues are referred to as memory intersections problems, or multiply constrained memory problems. The consideration of multiple cues in such problems can be done in parallel, when two (or more) cues are considered at the same time, or in serial, when one cue is considered after the other. The type of strategy, serial or parallel, is essential information for the development of theories of memory, yet evidence to date has been inconclusive. Using a novel application of the powerful Systems Factorial Technology (Townsend & Nozawa, 1995) we show participants use two cues in parallel in free recall tasks – a finding that contradicts two recent publications in this area. We then show that in a slightly modified variant of our method, constructed as a recognition task, most participants also use a parallel strategy but a reliable subset of participants used a serial strategy. Our findings provide important constrains for future theoretical development, point out strategy difference across recall- and recognition-based intersection memory tasks, and highlight the importance of tightly controlled methodological and analytic frameworks to overcome issues of serial/parallel model mimicry.

Using Context to Shift from Line to Point Attractors in a Bidirectional Associative Memory

CS

Church, Kinsey Antonina; Ross, Matt; Chartier, Sylvain

University of Ottawa, Canada

One challenge for artificial neural networks is stabilizing on a desired response in a previously learned series of responses. This process is akin to going from a line to a point attractor. Since a single pattern can lead to multiple outcomes, the network faces a one-to-many problem. Using context, information given by the environment, is proposed in order to differentiate between the stimuli associated with themselves (point attractor) and the next in the series (line attractor). To test this with multi-step pattern time series, a Bidirectional Associative Memory (BAM) is used with alphanumeric stimuli as inputs. These stimuli are arranged in three different series of increasing difficulties where letters represent the stimuli and numbers represent the context: one long time series, two time series of different lengths, and three independent time series. Each of these time series has its own identifying numeric context. To determine which letter the BAM needs to converge

on, the desired response in the specified context is compared with the output at each iteration during recall. When the desired response is reached, the context is changed, causing the network to switch attractors and therefore allowing the BAM to correctly stabilize on the desired output. This provides an effective solution to the one-to-many problem and allows the BAM to stabilize on the desired response, regardless of the length of the series or level of correlation between stimuli. This could represent how the most effective behaviour is selected from a series of behaviours to solve a given problem.

No distinction between 'capacity' and 'precision': Populations of noisy familiarity signals explain visual memory errors

CS

Brady, Timothy; Schurgin, Mark; Wixted, John

University of California, San Diego

Over the past decade, many studies have used mixture models to interpret continuous report memory data, drawing a distinction between the number of items represented the precision of those representations (e.g., Zhang & Luck, 2008). Such models, and subsequent expansions of these models to account for additional phenomena like variable precision, have led to hundreds of influential claims about the nature of consciousness, working memory and long-term memory.Here we show that a simple generalization of signal detection theory (termed TCC – target confusability competition model – https://bradylab.ucsd.edu/tcc/) accurately accounts for memory error distributions in much more parsimonious terms, and can make novel predictions that are entirely inconsistent with mixture-based theories. For example, TCC shows that measuring how accurately people can make discriminations between extremely dissimilar items (study red; then report whether studied item is red vs. green) is completely sufficient to predict, with no free parameters, the entire distribution of errors that arises in a continuous report task (report what color you saw on a color wheel). Because this is inconsistent with claims that the continuous report distribution arises from multiple distinct parameters, like guessing, precision, and variable precision, TCC suggests such distinctions are illusory.Overall, with only a single free parameter – memory strength (d') – TCC accurately accounts for data from n-AFC, change detection and continuous report, across a variety of working memory set sizes, encoding times and delays, as well as accounting for long-term memory continuous report tasks. Thus, TCC suggests a major revision of previous research on visual memory.

A Bayesian Model of Capacity Across Time

CS

Fox, Elizabeth (1,2); Houpt, Joseph (1)

1: Air Force Research Labs, Wright-Patterson AFB, Ohio; 2: Wright State University, Dayton, Ohio

In this work we derive and illustrate a Bayesian time series model of the capacity coefficient to investigate processing efficiency across time. The workload capacity coefficient is a well-established measure from systems factorial technology that

allows researchers to quantify a participant's multisource information processing efficiency. In most applications of the capacity coefficient, the analyses assume stationary performance across time. However, in many contexts participants' performance varies across time (e.g., vigilance decrements, training). This variation could be either due to changes in processing each source or the efficiency of combining the sources. A time-varying capacity measure would be valuable in determining the nature of the change over time, but dropping the stationarity assumption results in a severe loss in power. In an attempt to estimate a time-varying capacity coefficient, we developed a measure relying on Bayesian estimation. We used the Weibull distribution to approximately characterize the processing time of each source, with an inverse gamma distribution prior for the scale parameter and a known shape. This provided us a tractable way to update our prior estimate for real-time estimation of capacity. The prior was updated by weighting the observation's contribution to the likelihood by how recently they occurred. Samples from the posterior Weibull estimates were then combined using the appropriate capacity coefficient equation to obtain posterior distributions for the capacity coefficient. We demonstrate the approach with both simulated and human data. We believe the time-varying capacity coefficient will be a valuable tool for measuring cognitive tasks such as adaptive interface design.

A General Architecture for Modeling the Dynamics of Goal-Directed Motivation and Decision Making

CS

Ballard, Timothy (1); Neal, Andrew (1); Farrell, Simon (2); Heathcote, Andrew (3)

1: The University of Queensland; 2: The University of Western Australia; 3: The University of Tasmania

We present a unified model of the spatial and temporal dynamics of motivation during goal pursuit. We use the model to integrate and compare six theoretical perspectives that make different predictions about how motivation changes as a person comes closer to achieving a goal, as a deadline looms, and as a function of whether the goal is being approached or avoided. We fit the model to data from three experiments that examine how these factors combine to produce changes in motivation over time. We show that motivation changes in a complex manner that cannot be accounted for by any one previous theoretical perspective, but that is well-characterized by our unified model. Our findings highlight the importance of theoretical integration when attempting to understand the factors driving motivation and decision making in the context of goal pursuit.

A framework for the formal operational description of ACT-R.

CS

Langenfeld, Vincent; Westphal, Bernd; Podelski, Andreas

University of Freiburg, Germany

Psychological theories can be validated by comparing the predictions of an ACT-R model, which implements the psychological theory, to experimental data. For this approach, the model needs to be valid, i.e., the implementation of the model must

not contain defects that skew the model's predictions and may thus lead to acceptance of an incorrect psychological theory or vice versa. In recent work we presented formal analysis methods allowing for the exhaustive exploration of ACT-R models for defects. These methods rely on manual formalizations of ACT-R models and of the architecture, which determines possible model executions (e.g., by rule selection or buffer actions). Both formalization steps present threats to the validity of the analysis: Defects in an ACT-R model may remain undetected in case of errors. Our contribution addresses both formalization activities. We present a Timed Automata based framework for the operational formal description of cognitive architectures. The framework defines interfaces and invariants such that each implementation of the interface (by particular formalizations of modules) supports the execution of ACT-R model formalizations. We provide one exemplary implementation as a formalisation of ACT-R's textual architecture description. Given the well-structured formalisation of the architecture, the formalisation of a model can be automatised. Overall, we obtain an automatic analysis of ACT-R models for defects on a formal model of the ACT-R architecture, as well as a strong perspective for the definition and analysis of other module implementations or whole other architectures.

Computational Model-Based Cognitive Neuroscience

Combining hierarchical latent-mixture and evidence accumulation-based models with fMRI data

Mistry, Percy; Supekar, Kaustubh; Menon, Vinod

SY

Stanford University

We show how the functional resolution of mapping neural circuit features to distinct cognitive and behavioral components of decision-making process can be improved, by combining hierarchical latent-mixture and evidence-accumulation based models with neural (fMRI) data. These models are implemented within a Bayesian inference framework. Theory based and structural assumptions are used to develop evidence accumulation models whose parameters are hierarchically governed by cognitive subsystems, such as performance monitoring, belief updating, error-feedback, and executive control. Such models explicitly account for the temporal dynamics and learning associated with repeated decision making. They dissociate between different potential cognitive processes and strategies that may be used on a trial-by-trial basis, and account for the hierarchical process of strategy switching. The hierarchical cognitive processes and subsystems are characterized by cognitive parameters that potentially capture and mediate the relationship between neural (fMRI) and behavioral data. Such neuro-cognitive modeling allows us to differentiate between theories, provide insights into the developmental maturation of brain networks, and improve the identification of differential brain feature characteristics associated with different cognitive processes in clinical and neuro-diverse populations. Applications include identifying the joint neural and behavioral basis of individual

differences in mathematical decision making, response inhibition, and perceptual decision making tasks.

Extensions of Multivariate Dynamical Systems to Simultaneously Explain Neural and Behavioral Data

SY

Liu, Qingfang (1); Petrov, Alexander A. (1); Lu, Zhong-lin (2,3); Turner, Brandon (1)

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To examine how the brain produces behavior, new statistical methods have linked neurophysiological measures directly to mechanisms of cognitive models, modeling both modalities simultaneously. However, current simultaneous modeling efforts are largely based on either correlational methods or on functions that map one stream of data to the other. Such frameworks are limited in their ability to infer causality between brain activity and behavior. We investigate one causal framework for explaining how behavior can be viewed as an emergent property of brain dynamics. Our proposed framework can be considered an extension of multivariate dynamical systems (MDS; Ryali et al. Neuroimage, 54(2), 807–823, 2011), as it is constructed with temporal dynamics and brain functional connectivities. To test the MDS framework, we formulate a concrete model, demonstrate that it generates reasonable predictions about both behavioral and fMRI data, and conduct a parameter recovery study. Specifically, we develop a generative model of perceptual decision-making in a visual motion-direction discrimination task. Two simulation studies under different experimental protocols illustrate that the MDS model can capture key characteristics of both behavioral and neural measures that typically occur in experimental data. We also examine whether or not such a complex system can be inferred from experimental data by evaluating whether current algorithms for fitting models to data can recover sensible parameter estimates. Our parameter recovery study suggests that the MDS parameters can be recovered using likelihood-free estimation techniques. Together, these results suggest that our MDS-based framework shows great promise for developing fully integrative models of brain-behavior relationships.

Hidden Markov model approaches and Bayesian methods to investigate brain dynamics and cognitive-state switching in children

SY

Supekar, Kaustubh; Ryali, Srikanth; Menon, Vinod

Stanford University

Characterizing the temporal dynamics of functional interactions between distributed brain regions is of fundamental importance for understanding human brain organization underlying higher-order cognition. Progress in the field has been hampered both by a lack of strong computational techniques to investigate brain dynamics and an inadequate focus on core brain systems involved in higher-order cognition. Here

we address these gaps by developing a novel variational Bayesian Hidden Markov Model (VB-HMM) that uncovers non-stationary dynamical functional networks in human fMRI data. VB-HMM revealed multiple short-lived cognitive states characterized by rapid switching and transient connectivity between the salience (SN), default mode (DMN), and central executive (CEN) networks—three brain systems critical for higher-order cognition. Notably, in children, relative to adults, VB-HMM revealed immature dynamic interactions between SN, CEN, and DMN, characterized by higher mean lifetimes in individual states, reduced switching probability between states and less differentiated connectivity across states. Our findings suggest that the flexibility of switching between distinct cognitive states is weaker in childhood, and they provide a novel framework for modeling immature brain network organization in children. More generally, the approach used here may be useful for investigating brain dynamics in neurodevelopmental disorders with deficits in higher-order cognition.

Linking functions for mind, brain and behavior

Turner, Brandon

SY

The Ohio State University

To better understand human behavior, the emerging field of model-based cognitive neuroscience seeks to anchor psychological theory to the biological substrate from which behavior originates: the brain. Despite complex dynamics, many researchers in this field have demonstrated that fluctuations in brain activity can be related to fluctuations in components of cognitive models, which instantiate psychological theories. In this talk, I will describe a statistical framework (joint modeling) that links computational models of behavior to neuroimaging data by exploiting patterns of covariation between the streams of data. I will then describe a number of recent advancements that address issues pertaining to scalability, determining significance of brain-behavior connections, and continuous spatio-temporal dynamics

Understanding individual differences in Rhesus macaques' strategies for visual evidence accumulation

CS

Nunez, Michael D.; Kadambi, Vaishnavi; Jun, Elizabeth J.; Basso, Michele A.

University of California, Los Angeles

Human choices and response times during two-alternative forced choice visual tasks are well described by evidence accumulation to a fixed bound. However the mechanism deployed by other non-human primates (Rhesus macaques) during similar visual tasks has been shown to better match short time-scale evidence accumulation with an urgency signal or collapsing boundary in some experiments. While other experiments in monkeys suggest evidence accumulation to a fixed bound. We present evidence from three monkeys showing that the strategy used to accumulate evidence during a Glass Pattern orientation task with saccadic responses varies by monkey, and thus the decision-making model that best fits the data depends upon the particular monkey. Specifically we compared these monkeys' data across multiple experimental sessions using various methods to fit Drift-Diffusion models (DDM) with stable and collapsing boundaries and Urgency Gating models (UGM). One monkey's data was particularly well fit to a UGM while another monkey's data was well fit by a simple DDM. Best fit models were evaluated with in-sample and out-of-sample prediction of choice and RT quantiles as well as Bayesian Information Criterion (BIC). We confirmed parameter recovery of these models with Hierarchical Bayesian estimation and Quantile Maximum Products Estimation. While the evidence accumulation parameters of these monkeys remained relatively stable over multiple experimental sessions, parameters not in direct control of evidence accumulation changed with experimental session. We discuss the possibility that the training paradigm used for monkeys has a role in model recovery, and we discuss the implications for the study of human decision-making.

Single-trial estimates of sequential sampling models parameters are not just noisy but can also be biased

CS

Fontanesi, Laura (1); de Hollander, Gilles (2); Gluth, Sebastian (1); Rieskamp, Jörg (1)

1: University of Basel, Switzerland; 2: University of Zurich, Switzerland

Traditionally, researchers estimate parameters of sequential sampling models (SSMs) from repeated choices across different conditions. Crucially, differences in parameters across conditions are interpreted as shifts in the underlying cognitive processes: For example, lower decision thresholds under high time pressure are interpreted as decreased cautiousness. Recent work has explored whether the parameters of SSMs can be estimated at a more detailed, single-trial level as well, to infer shifts in cognitive processes in subsequent trials. Such a more detailed window on decision-making processes has exciting applications. For example, by correlating single-trial

estimates to neuroimaging data, we can relate specific brain areas to cognitive processes that may vary from trial to trial and not merely across conditions. The present work highlights some important limitations of such a powerful approach. First, we reproduce earlier work and show that single-trial estimates of SSM parameters are extremely noisy. We also show that single-trial SSM parameter estimates can be highly biased by the outcome of a choice. For example, single-trial estimates of the rate of evidence accumulation in incorrect choices are severely underestimated when compared to the generating single-trial parameter (and vice versa for correct choices). We will show how these problems can pollute the cognitive interpretation of single-trial parameters and can be exacerbated by correlations to process data. Finally, we offer a potential solution where SSMs that incorporate more information about trial-to-trial differences (e.g., stimulus or feedback properties) produce more reliable single-trial estimates.

Assessing model-based inferences in decision making with single-trial response time decomposition

Weindel, Gabriel (1,2); Anders, Royce (1,3); Alario, F.-Xavier (1,4); Burle, Boris (2)

CS

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Decision-making models based on evidence accumulation processes (the most prolific one being the drift-diffusion model – DDM) are widely used to draw inferences about latent psychological processes from chronometric data. While the observed goodness of fit in a wide range of tasks supports the model's validity, the derived interpretations have yet to be sufficiently cross-validated with other measures that also reflect cognitive processing. To do so, we recorded electromyographic (EMG) activity along with response times (RT), and used it to decompose every RT into two components: pre-motor (PMT) and motor time (MT). These measures were mapped to the DDM's parameters, thus allowing a test, beyond quality of fit, of the validity of the model's assumptions and some of their usual interpretation. In two perceptual decision tasks, performed within a canonical task setting, we manipulated stimulus contrast, speed-accuracy trade-off, and response force, and assessed their effects on PMT, MT, and RT. Contrary to common assumptions, the three factors consistently affected MT. DDM parameter estimates of non-decision processes are thought to include motor execution processes, and they were globally linked to the recorded response execution MT. However, when the assumption of independence between decision and non-decision processes was not met, in the fastest trials, the link was weaker. Overall, the results show a fair concordance between model-based and EMG-based decompositions of RTs, but also establish some limits on the interpretability of decision model parameters linked to response execution.

Changes within neural population codes can be inferred from psychophysical threshold studies

CS

Hays, Jason; Soto, Fabian

Florida International University

The use of population encoding models has come to dominate human visual neuroscience, serving as a primary tool that allows researchers to infer, through indirect measurements, how cognitive states (i.e., attentional shifts, learning, adaptation, etc) change neural stimulus representations. Inverted encoding modeling is commonly used to retrieve estimates of neural population responses from neuroimaging data, but recent results suggest that the approach may have identifiability problems, because multiple mechanisms of encoding change can produce similar neural responses. Psychophysical data might be able to provide additional constraints to infer the encoding change mechanism underlying some behavior of interest. Here, we explored how well eight different mechanisms of encoding change could be differentiated by comparing the relative change between psychophysical thresholds across states. The eight types (previously proposed in the literature as mechanisms for improved task performance) included specific and nonspecific gain, specific and nonspecific tuning, specific suppression, specific suppression plus gain, and inward and outward tuning shifts. For each of the eight types (plus a homogeneous baseline), Monte Carlo simulations were used to obtain thresholds along the stimulus domain (a threshold vs stimulus function, or TvS) or along levels of external noise (a threshold vs noise function, or TvN). With the exception of specific gain and specific tuning, all studied mechanisms produced qualitatively different patterns of change in the TvN and TvS curves, suggesting that psychophysical studies can be used as a complement to inverted encoding modeling and provide strong constraints on inferences based on the latter.

Perceptual decision-making in children: Age-related differences and EEG correlates

CS

Manning, Catherine (1); Wagenmakers, Eric-Jan (2); Norcia, Anthony M. (3); Scerif, Gaia (1); Boehm, Udo (2)

1: University of Oxford, United Kingdom; 2: University of Amsterdam, The Netherlands; 3: Stanford University, USA

Children make better decisions about perceptual information as they get older, but it is unclear how different aspects of the decision-making process change with age. Here, we used hierarchical Bayesian diffusion models to decompose performance in a perceptual task into separate processing components, testing age-related differences in model parameters and links to neural data. We collected behavioural and EEG data from 96 six- to twelve-year-olds and 20 adults completing a motion discrimination task. We used a component decomposition technique to identify two response-locked EEG components with ramping activity preceding the response in children and adults: one with activity that was maximal over centro-parietal

electrodes and one that was maximal over occipital electrodes. Younger children had lower drift rates (reduced sensitivity), wider boundary separation (increased response caution) and longer non-decision times than older children and adults. Yet model comparisons suggested that the best model of children's data included age effects only on drift rate and boundary separation (not non-decision time). Next we extracted the slope of ramping activity in our EEG components and covaried these with drift rate. The slopes of both EEG components related positively to drift rate, but the best model with EEG covariates included only the centro-parietal component. By decomposing performance into distinct components and relating them to neural markers, diffusion models have the potential to identify the reasons why children with developmental conditions perform differently to typically developing children - and to uncover processing differences which are not apparent in the response time and accuracy data alone.

Theory Development

How computational modeling can force theory building in psychological science

Guest, Olivia (1); Martin, Andrea (2)

SY

1: Research Centre on Interactive Media, Smart Systems and Emerging Technologies – RISE, Nicosia, Cyprus & Department of Experimental Psychology, UCL, UK; 2: Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands & Donders Centre for Cognitive Neuroimaging, Radboud University, Nijmegen, The Netherlands

Psychology endeavors to develop theories of human capacities and behaviors based on a variety of methodologies and dependent measures. We argue that one of the most divisive factors in our field is whether researchers choose to employ computational modeling of theories (over and above data) during the scientific inference process. Modeling is undervalued, yet holds promise for advancing psychological science. The inherent demands of computational modeling guide us towards better science by forcing us to conceptually analyze, specify, and formalise intuitions which otherwise remain unexamined – what we dub "open theory." Constraining our inference process through modeling enables us to build explanatory and predictive theories. Herein, we present scientific inference in psychology as a path function, where each step shapes the next. Computational modeling can constrain these steps, thus advancing scientific inference over and above stewardship of experimental practice (e.g., preregistration). If psychology continues to eschew computational modeling, we predict more replicability "crises" and persistent failure at coherent theory-building. This is because without formal modelling we lack open and transparent theorising. We also explain how to formalise, specify, and implement a computational model, emphasizing that the advantages of modeling can be achieved by anyone with benefit to all.

Clarifying the role of mathematics in theory development

SY

Donkin, Chris; Szollosi, Aba; Hotaling, Jared

University of New South Wales

Though formal implementations of theories can be useful, they are not necessarily so. So, while a good theory is one that lends itself to being implemented formally, a good model does not guarantee a good theory. The scope of what can be learned from a mathematical model is based on the extent to which that model is implied by its motivating theory, and, therefore, what implications the failure of a model has for that theory. We discuss common use of mathematics in psychology, such as model fitting and model selection, with these limitations in mind.

Generating theories are hard, and none of our theories are good enough

SY

Perfors, Amy

University of Melbourne

One response to the ongoing replication crisis in the social sciences has been the observation that solutions such as pre-registration become less necessary (or perhaps even unnecessary) when experiments and analyses are constrained by good theory. In this talk I will discuss what characteristics are necessary for a theory to be good enough to play this role effectively. I will argue that in all or almost all areas of psychology – including mathematical psychology – existing theories and computational models do not have these characteristics. I will conclude by discussing what can be learned from not good enough theories and will offer some thoughts on how to create better ones given the epistemological and practical problems inherent in doing science in the real world.

Good theories are possible

SY

van Rooij, Iris

Radboud University

A common adage is 'good theories make testable predictions', which fits a view of science as progressing solely via the empirical cycle (i.e. the iterative process of revising theories by deriving and testing predictions). This view has led, however, to a relative neglect of good theory building prior to testing. Even in subfields strong in theory, such as mathematical psychology and computational cognitive science, theories are put to empirical tests without considering if they provide possible explanations for target phenomena. We may come away thinking our theories are empirically supported while the processes they postulate are in fact impossible. I use one species of impossibility – intractability – as an illustration. I will distill some general lessons and conclude that the empirical cycle is best complemented by an equally important theoretical cycle (i.e. the iterative process of refining theories to postulate only possible processes).

Theories that explain versus theories that describe: the case of constraint satisfaction

SY

Varma, Sashank

University of Minnesota Duluth

Theories, by which I mean formal theories rendered in mathematical or computational formalisms, are commonly understood as describing the data on human cognition, or as implementing a computational (in the sense of Marr) specification of cognition. Beyond these functions, we also desire theories that explain the phenomena of cognition. Three scenarios where a new theory seems to explain cognition are: (1) the development of a new mechanism that captures empirical anomalies beyond the reach of existing theories; (2) the proposal of a new theory that provides a unified account of domains previously thought to be independent; and (3) the importation of a new formalism into cognitive science that supports theories that seem to effortlessly account for large swaths of cognition. In these scenarios, a new theory explains in part by offering a new perspective on cognition, one that directly captures phenomena without much need for tedious, low-level calculation. We illustrate these claims by considering the case of constraint satisfaction theories of cognition in some depth.

Theories as Modelling Ecologies

SY

Kellen, David

Syracuse University

The goal of this talk is to argue that the question 'what makes a good theory?' cannot be posed in isolation, as it first requires us to engage in some division of labor between theories and models. I will provide a brief philosophical review on the theory-model dyad and highlight some of the different ways that scientists have understood them throughout history. I will then argue that psychologists have often failed to hold a clear distinction between models and theories, which has had many nefarious consequences. Among these is a failure to acknowledge the 'problem of coordination', and the failure to understand that any model comparison is always a socio-linguistic exercise, as it involves communities with specific goals and sensitivities.

Adaptive Reasoning in Rock-Paper-Scissors

CS

Brockbank, Erik; Vul, Edward

University of California, San Diego

Human conflict and coordination relies on our ability to reason about and predict the behavior of others. We investigate how people adapt to and exploit their opponents in repeated adversarial interactions through iterated play of Rock-Paper-Scisssors (RPS). In Experiment 1, we investigate naturalistic adversarial interactions between two humans. Participants ($N = 116$) played 300 rounds of RPS in 58 stable dyads. We find that the distribution of win count differentials differs significantly from Nash equilibrium random play ($\chi^2(5) = 133.27, p < 0.001$), suggesting that many participants are able to exploit dependencies in their opponent's move choices. However, expected win count differentials based on observed regularities in participant behavior reveal that people fail to maximally exploit their opponents. This raises the question of what kinds of patterned behavior people are able to detect and exploit.In Experiment 2, participants ($N = 217$) were paired against bots employing stable RPS strategies. We tested seven strategies that parametrically varied the number and source of their behavioral regularities. This allowed us to establish levels of complexity that people exploit maximally, partially, and not at all. For partially exploitable bots, participants reach close to maximal exploitation of subparts of the bot's strategy, with chance performance otherwise, suggesting that people are selectively sensitive to particular patterns of opponent behavior.Our results show that the ability to exploit opponents in adaptive settings relies on successful detection of a limited set of patterns. A concrete understanding of the inputs people use to predict others provides insight into how people establish cooperative behavior, and why it sometimes fails.

A rate-distortion theory analysis of human bounded rational learning

CS

Fang, Zeming; Sims, Chris R.

Rensselaer Polytechnic Institute

In recent years, computational reinforcement learning (RL) has become an influential normative framework for understanding human learning and decision-making. However, unlike the RL algorithms developed in machine learning, human learners face strict limitations in terms of information processing capacity. For example, human learning performance decreases as the number of possible states of the environment increases, even when controlling for the amount of experience with each environmental state. Collins and Frank [2012; European Journal of Neuroscience, 35(7), 1024-1035] demonstrated this experimentally in a simple instrumental learning task. Different conditions of their experiment manipulated the "set size" of visual

stimuli to which subjects had to respond, and they showed that learning efficiency decreased monotonically with set size in a manner incompatible with standard RL algorithms. They interpreted the sub-optimality of human learning performance in terms of decay in human working memory. Our work proposes an alternative explanation for this phenomenon, based on the idea of bounded rationality. We propose that human learners navigate a trade-off between maximizing task performance, and minimizing the complexity of the learned action policy, where policy complexity is formalized in terms of information theory. We apply an RL model with this approach to the Collins and Frank dataset and we achieve a comparable fit to their models. The modeling result shows consistency with our hypothesis: human learners trade part of expected utility for simpler action policy due to their own information processing limitations.

Differences in learning process dynamics when rewards are familiar versus instructed

CS

Baribault, Beth; Collins, Anne

University of California, Berkeley

Most reinforcement learning (RL) experiments use familiar reinforcers, such as food or money, which are relatively objectively rewarding. However, in everyday life, teaching signals are rarely so straightforward — often we must learn from the achievement of subgoals (e.g., high heat must be achieved before cooking), or from feedback that we have been instructed to perceive as reinforcement, yet is not intrinsically rewarding (e.g., grades). As such, investigating how similar the dynamics of learning from familiar rewards, which are well-studied, are to the dynamics of learning from subgoals and instructed rewards, which are more realistic, can help us to understand the ecological validity of laboratory reinforcement learning research.In this talk, we discuss our recent work investigating these potential similarities using computational modeling, while emphasizing individual differences. In our experiment, participants completed a probabilistic RL task, comprising multiple interleaved two-armed bandit problems, and an N-back task. Some bandits were learned using points, a familiar reward, while others were learned based on whether their selection lead to a “goal image” unique to each trial, an instructed reward. In the instructed condition, participants tended to learn more slowly, and each participant’s performance correlated with their working memory ability. Hierarchical Bayesian model comparison revealed that differences in behavior due to feedback type were best explained by a lower learning rate for instructed rewards, although this effect was reversed or absent for some participants. These strong individual differences suggest that differences in learning dynamics between familiar and instructed rewards may not be universally applicable.

Dissecting the mechanism of Pavlovian bias with the orthogonalized Approach/Withdrawal task and mouse-tracking

CS

Doh, Hoyoung (1); Jeong, Yunseo (2); Park, Harhim (1); Ahn, Woo-Young (1)

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The brain has multiple systems for decision-making such as instrumental and Pavlovian systems. Pre-programmed Pavlovian responses such as approach towards appetitive outcomes or freezing/withdrawal from aversive outcomes afford animals useful shortcuts for behavior but overcoming such Pavlovian bias is often necessary for achieving long-term instrumental goals. The orthogonalized Go/Nogo task (Guitart-Masip et al., 2012) is widely used to examine Pavlovian bias, but it has certain limitations. First, Pavlovian bias is observed only when learning appetitive outcomes, but not when learning aversive outcomes in the task. Second, while aversive outcomes may cause either freezing or withdrawal, the task cannot differentiate the contribution of the two response types. Third, it only yields final behavior responses but provides no information about the time-course of cooperation or competition between the two systems. To address the limitations, we developed a new version of the orthogonalized Go/Nogo task with mouse-tracking, called the orthogonalized Approach/Withdrawal task, requiring an active response on every trial. Seventy-seven healthy participants performed the task and we found they showed Pavlovian bias both for stimuli predicting appetitive and aversive outcomes. Computational modeling with hierarchical Bayesian parameter estimation also revealed their strong Pavlovian and approach biases. These results were replicated in an independent experiment where participants used keyboard buttons instead of a mouse. Mouse-tracking results suggest that Pavlovian responses to aversive cues are rather withdrawal than freezing and that response pathways are shorter for approach than withdrawal.

Analyzing variability in instance-based learning model predictions using recurrence quantification analysis

CS

McCormick, Erin (1,2); Blaha, Leslie M (3); Gonzalez, Cleotilde (4)

1: Carnegie Mellon University, Pittsburgh, Pennsylvania; 2: ORISE at the Air Force Research Laboratory, Pittsburgh, Pennsylvania, United States; 3: 711th Human Performance Wing, Air Force Research Laboratory, Pittsburgh, Pennsylvania, United States; 4: Dynamic Decision Making Laboratory, Carnegie Mellon University, Pittsburgh, Pennsylvania

Model variability is important: if systematic variation in model predictions does not reflect systematic variation in human behavior, the model's ability to describe, predict, and explain behavior is in question. We demonstrate a method to compare variation in model predictions to variation in human behavior in a dynamic decision making task. Dynamic decisions are a sequence of inter-dependent choices in changing environments, where human choices may systematically change over time. We can characterize these changes with a qualitative and quantitative visual

analytics approach, recurrence quantification analysis (RQA). RQA visualizes (with recurrence plots) and describes (with recurrence statistics) recurring states in sequences of observations. We compared human choice sequences in a dynamic decision making task to predictions of an instance-based learning (IBL) model, a memory-based model of choice with two parameters (noise and decay). Specifically, we generated predictions using two parameterizations of the IBL model: one using default noise and decay parameters from the ACT-R cognitive architecture, another using the average of noise and decay parameters from IBL models fit to human data at the individual level. We compared the recurrence statistic distributions of the human data and both parameterizations. We find ACT-R default parameters predict more decision makers with less trial-to-trial change in choices than in human data. In contrast, the averaged parameters predict more decision makers with more trial-to-trial change in choices than in human data. RQA provides new tools for assessing model predictions, and a new source of evidence for demonstrating that models successfully characterize sequences of human choice.

Optimality in Choice

A model of target position effects in a sequential lineup.

Dunn, John (1,2); Kaesler, Matthew (3); Semmler, Carolyn (3)

CS

1: University of Western Australia; 2: Edith Cowan University; 3: The University of Adelaide

Forensic lineups are used to test a witness' memory for the perpetrator of a crime. While they often take the form of a photo array presented simultaneously to the witness, in many jurisdictions, the lineup items are presented sequentially. Although decision rules vary, in its simplest form, the witness makes a decision concerning the identity of each item in the sequence before being presented with the next. Of both applied and theoretical interest is whether the location of the perpetrator (or target) in the lineup affects the probability of correct identification. To answer this question, it is necessary to develop, test, and evaluate a model of the sequential lineup task. We outline this model and apply it to data we recently collected as well as data reported by Wilson, Donnelly, Christenfeld, and Wixted (2019, Journal of Memory and Language, 104, 108-125). The two sets of data reveal similar results. There are little or no target position effects on discriminability but substantial effects on decision criteria including a short-lived increase following a failure to detect the target. We discuss the implications of these results for the interpretation of sequential lineup identifications.

Response time models separate single- and dual-process accounts of memory-based decisions

Kraemer, Peter Maximilian (1); Fontanesi, Laura (1); Spektor, Mikhail S (2,3); Gluth, Sebastian (1)

1: University of Basel, Switzerland; 2: Universitat Pompeu Fabra, Barcelona; 3: Barcelona Graduate School of Economics

Human decisions often deviate from economic rationality and are influenced by cognitive biases. One such bias is the memory bias according to which people prefer choice options they have a better memory of—even when the options' utilities are comparatively low. Although this phenomenon is well supported empirically, its cognitive foundation remains elusive. Here we test two conceivable computational accounts of the memory bias against each other. On the one hand, a single-process account explains the memory bias by assuming a single biased evidence-accumulation process in favor of remembered options. On the contrary, a dual-process account posits that some decisions are driven by a purely memory-driven process and others by a utility-maximizing one. We show that both accounts are indistinguishable based on choices alone as they make similar predictions with respect to the memory bias. However, they make qualitatively different predictions about response times. We tested the qualitative and quantitative predictions of both accounts on behavioral data from a memory-based decision-making task. Our results show that a single-process account provides a better account of the data, both qualitatively and quantitatively. In addition to deepening our understanding of memory-based decision making, our study provides an example of how to rigorously compare single- versus dual-process models using empirical data and hierarchical Bayesian estimation methods.

Single vs. dual process theories of reasoning in a Bayesian signal detection theory framework

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1: University of New South Wales; 2: University of Adelaide; 3: The University of Western Australia; 4: University of California, Irvine

A central question in the psychology of reasoning is whether people use similar functions and processes to make deductive and inductive inferences, or whether deduction and induction are fundamentally distinct forms of thinking. Dual process theories distinguish two distinct types of thinking: Type 1 is said to be intuitive, heuristic and independent of working memory, and Type 2 deliberative, analytic, and reliant on working memory. Type 2 thinking is often considered uniquely qualified to compute the functions that define deduction. In contrast, single process theories argue that the dual process distinction is unnecessary, and point to Bayesian probabilistic logic as a shared basis for deduction and induction. How can these approaches be differentiated empirically? Much research in this area has relied on verbal theories and the measurement of dissociations in experiments. But these

provide only limited information. More recent work has begun to formalise the theories e.g. in a signal detection theory framework, to compare them using more advanced modelling techniques. We present four signal detection theory models of reasoning within a Bayesian framework: two single process models, one with independent and the other with dependent decision criteria for deduction and induction, and two dual process models, again one with independent and the other with dependent decision criteria. We then assess the descriptive adequacy of the models across three different distributional assumptions: normal, binomial and beta, following the idea of a multiverse or sensitivity analysis. We discuss the implications of our results for the single-dual process theory debate.

A solution to the feature binding problem for risky choice

CS

He, Lisheng; Bhatia, Sudeep

University of Pennsylvania

Sequential sampling models describe the cognitive mechanisms at play in preferential decision making. These models can predict attention, choice, and response time in simple choices, but are currently unable to specify how decision-makers deliberate in more complex settings, such as those involving multi-branch gambles. To make rational decisions for such gambles, decision-makers need to compute interactions between payoffs and probabilities. Current sequential sampling models, which model information sampling as sequentially independent, are unable to capture within-branch attribute interactions, and thus make absurd predictions for multi-branch gambles. This is analogous to the feature binding problem in cognitive science, which involves the integration of the perceptual properties of objects. In this paper, we propose a solution to the feature binding problem for risky choice. Specifically, we propose that attribute sampling in multi-branch gambles is sequentially non-independent and that decision-makers are more likely to sample the probability of a branch if they observe a highly desirable payoff in that branch (and vice versa). We show that such a non-independent sampling process allows sequential sampling models to make utility-maximizing predictions. We test our model on data from four existing Mouselab and eye-tracking experiments, and two novel Mouselab experiments, and find that most participants display the non-independent attribute sampling proposed by our model. Additionally, we show that participants who display stronger non-independent sampling are also less likely to deviate from expected value/utility maximization. Overall, our results show how feature binding implemented in existing sequential sampling models can be used to predict sophisticated risky choice behavior.

Anxiety Modulates Preference for Immediate Rewards among Trait-Impulsive Individuals: A Decision Theory and Hierarchical Bayesian Analysis

Haines, Nathaniel (1); Beauchaine, Theodore (1); Galdo, Matthew (1); Rogers, Andrew (2); Hahn, Hunter (1); Pitt, Mark A. (1); Myung, Jay I. (1); Turner, Brandon (1); Ahn, Woo-Young (3)

CS

1: The Ohio State University; 2: University of Houston; 3: Seoul National University, South Korea

Trait impulsivity—defined by strong preference for immediate over delayed rewards and difficulties inhibiting prepotent behaviors—is observed in all externalizing disorders, including substance use disorders. Many laboratory tasks have been developed to identify cognitive mechanisms and correlates of impulsive behavior, but convergence between task measures and self-reports of impulsivity are consistently low. Longstanding theories of personality and decision-making predict that neurally mediated individual differences in sensitivity to reward cues versus punishment cues (frustrative non-reward) interact to affect behavioral tendencies. Such interactions obscure 1:1 correspondences between single personality traits and task performance. Here, we develop models within the framework of decision theory that provide an explanation for how impulsive and anxious valuation may interact at the mechanistic level to produce observed interactions at the level of behavior. We then use hierarchical Bayesian analysis to fit these models to three samples with differing levels of substance use, trait impulsivity, and state anxiety (total $N = 967$). Our findings: (1) reveal cognitive mechanisms through which anxiety can modulate impulsive valuation and subsequently attenuate impulsive behavior, and (2) demonstrate benefits of decision theory and hierarchical Bayesian analysis over traditional approaches for testing theories of psychopathology spanning levels of analysis.

Gaussian Process Joint Models for Estimating Latent Dynamics of Brain and Behavior

CS

Bahg, Giwon; Evans, Daniel G.; Galdo, Matthew; Turner, Brandon

The Ohio State University

For bridging implementational and algorithmic levels of analysis (Marr, 1982), Bayesian joint models (Turner et al., 2013) have been applied for investigating shared statistical constraints between neural activities and cognitive model parameters. However, the previous joint modeling approach has assumed linearity in its linking function, which might not always be ideal when dealing with complex brain dynamics. Moreover, joint models based on covariance estimation often sacrifice the temporal dynamics of cognitive processes. As a solution to these limitations, we propose a Gaussian process joint model (GPJM), a data-driven and nonparametric joint modeling framework based on hierarchical Gaussian process latent variable models (Lawrence & Moore, 2007). In the GPJM, latent Gaussian processes serve as a linking function and model temporal dynamics governing neural and behavioral observations. The GPJM can incorporate spatiotemporal covariance structures as its constraints and evaluate the relevance of each latent dimension to the process of data generation. To verify the utility of the GPJM, we tested the model performance with simulation and an application to real data. The simulation results showed that the GPJM estimates cognitive dynamics while exploiting spatiotemporal constraints. In an fMRI experiment based on a continuous motion-tracking task, the GPJM explained the neural and behavioral data appropriately and also revealed non-trivial underlying dynamics that generate the data. Cross-validation analyses demonstrated that the latent dynamics trained with complete neural data and partially observed behavioral data could predict test data reasonably. How the latent dynamics could be interpreted is an open question.

Inferring Latent Learning Factors in Large-Scale Cognitive Training Data

CS

Steyvers, Mark (1); Schafer, Bob (2)

1: University of California, Irvine; 2: Lumos Labs, San Francisco

The flexibility to learn diverse tasks is a hallmark of human cognition. To improve our understanding of individual differences and dynamics of learning across tasks, we analyze the latent structure of learning trajectories from 36,297 individuals as they learned 51 different tasks on the Lumosity online cognitive training platform. Through a data-driven modeling approach using probabilistic dimensionality reduction, we investigate covariation across learning trajectories with few assumptions about learning curve form or relationships between tasks. Modeling results show significant covariation across tasks such that an entirely unobserved learning trajec-

tory can be predicted by observing trajectories on other tasks. The latent learning factors from the model include a general ability factor that is expressed mostly at later stages of practice, and additional task-specific factors that carry information capable of accounting for manually defined task features and task domains such as attention, spatial processing, language and math.

Towards a Quantitative Framework for Detecting Transfer of Learning

CS

Galdo, Matthew (1); Turner, Brandon (1); Steyvers, Mark (2)

1: The Ohio State University; 2: University of California, Irvine

Transfer of learning refers to how learning in one context influences performance in a different context. Because tasks are rarely performed in isolation, a well-versed theory of transfer is paramount to understanding learning. Yet, a thorough understanding of transfer has been frustratingly elusive, with some researchers arguing that meaningful transfer rarely occurs or attempts to detect transfer are futile. In spite of this pessimism, we explore a model-based account of transfer. Building on the laws of practice, we develop a scalable, quantitative framework to detect transfer (or lack thereof). We perform a simulation study to explore, under what conditions, can we detect transfer and the recoverability of the model. We then use our modeling framework to explore a large-scale gameplay dataset from Lumosity. Preliminary results suggest our model provides a reasonable account of the data and that the added complexity of transfer is justified.

Joint modeling of choices, response times, and eye movements

CS

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Over the past decade, the role of attention in value-based decision making has become a central research topic in cognitive psychology and neuroscience. On the basis of eye-tracking data, extensions of prominent sequential sampling models of decision making have been proposed, including the attentional Drift Diffusion Model (aDDM; Krajbich et al., 2010, Nature Neuroscience). These models take the influence of attention on preference formation into account and can thus be tested not only on choices and response times (RT) but also on eye-tracking data. Importantly, however, parameter estimation of these models has relied exclusively on choices and RT so far. This limitation is particularly problematic in light of recent evidence that attention itself can be influenced by preference formation (Gluth et al., 2020, Nature Human Behaviour). The goal of the present work was to overcome this restriction and to include eye-tracking data when estimating parameters of sequential sampling models. Using the aDDM and extensions of it, a general joint modeling approach for predicting choices, RT, and eye movements is presented. This approach combines extensive model simulations with probability density approximation and differential evolution Markov chain Monte Carlo sampling to enable hierarchical Bayesian parameter estimation. With respect to eye-tracking data, the approach

focusses on fixations and takes their latencies and locations into account. The proposed joint modeling technique is shown to provide a more sensitive comparison of different implementations of the aDDM. It promises to advance the research on computational modeling of attention and decision making substantially.

Bayesian analysis of risk- and ambiguity aversion in two information sampling tasks

CS

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UiT The Arctic University of Norway, Norway

Humans are aversive to risk (irreducible uncertainty) and ambiguity (reducible uncertainty). However, strong ambiguity aversion does not necessarily imply strong risk aversion. Further, in real life it can be challenging to attribute uncertainty and one may treat ambiguity as risk. This can lead to biases in information sampling, i.e. premature stopping of collecting information that could reduce uncertainty. These biases in information sampling have also been linked to delusional thinking and hallucination disposition in both healthy individuals as well as in mental disorders like schizophrenia. Modelling allows to identify the processes and aberrances in decision-making. Here, we experimentally investigate these potentially aberrant attributions by using the draws to decision version of the beads task (Huq et al., 1988) and the risk and ambiguity lottery task (Levy et al., 2010). For each participant ($N = 77$) we extracted their risk-, and ambiguity aversion using the hierarchical Bayesian modelling of Decision-Making tasks R-package (hBayesDM; Woo-Young et al., 2017), and used those parameters as predictors for explaining the draws to decision in the beads-task. Preliminary results indicate that a person's risk aversion but not ambiguity aversion is related to draws to decision in the beads task. This displays both the usefulness and importance of modelling cognitive tasks to better understand and analyze the results from decision-making tasks, as well as its importance in order to better understand and disentangle the underlying mechanisms of everyday biases.

Psychometrics

A MPT Model for Measuring the Memory of Order

CS

Chechile, Richard; Pintea, Giulia

Tufts University

An event in memory has many, qualitatively different, attributes. Besides the informational content, such as which word was presented on a list at a given time, there is also information about the temporal and ordinal properties of the event relative to other events. A MPT model is provided for measuring four different states for the memory of the order of any arbitrary event. The statistical properties of the model are described in this paper. In addition, the results from three experiments are provided. The experimental evidence shows that item knowledge is quickly acquired whereas the corresponding acquisition of ordinal information takes many more training trials.

Temporal structures in sensorimotor variability are reliable… but what for?

CS

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CUBRIC, School of Psychology, Cardiff University, UK

Human performance is characterised by endogenous variability, which often shows dependency over time. However, studies on these temporal structures typically stay limited to showing that the structures exist in a particular data series. As such, their underlying mechanisms and informativeness for cognitive psychology are largely unknown. Two recent studies reported between-subject correlations between temporal structures and task performance on the same data series, but with contrasting results. In the current work, we investigated the intra-individual repeatability and inter-individual correlates of temporal structures in sensorimotor variability across the most commonly used measures – aiming to examine to what extent these structures are informative for studying individual differences. To capture endogenous sensorimotor variability, participants completed the Metronome Task – in which they press in synchrony with a tone. Occasionally, participants were presented with a thought probe, and were asked to rate their current subjective attentional state. Results indicate that autocorrelation at lag 1 and Power Spectra Density (PDS) slopes show good repeatability, while Detrended Fluctuation Analysis (DFA) slopes only show moderate repeatability, and ARFIMA(1,d,1) repeats poorly. Autocorrelation and PSD, and DFA to a lesser extent, correlated with task performance on the same data series – such that well-performing participants showed less dependency. However, temporal structures did not correlate with mean attentional state ratings nor with self-assessed ADHD tendencies, mind wandering, and impulsivity – negating assumptions that these structures arise due to fluctuations in internal meta-cognitive states. Overall, while temporal structure may be a reliable trait, its usefulness for studying individual differences is yet to be identified.

Two Bayesian Corrections for Attenuation in Correlation Analysis to Investigate Unconscious Mental Processes

CS

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1: University College London, United Kingdom; 2: Universidad Autónoma de Madrid, Spain; 3: University of Sussex, United Kingdom

As a method to investigate the scope of unconscious mental processes, researchers frequently obtain concurrent measures of implicit task performance and explicit stimulus awareness across participants. Even though both measures might be significantly greater than zero, the correlation between them might not, encouraging the inference that an unconscious process drives task performance. We highlight the pitfalls of this null-correlation approach with reference to a recent study by Salvador, Berkovitch, Vinckier, Cohen, Naccache, Dehaene, and Gaillard (2018), who reported a non-significant correlation between the extent to which memory was suppressed by a Think/No-Think cue and an index of cue awareness. First, in the Null Hypothesis Significance Testing (NHST) framework, it is inappropriate to interpret failure to reject the null hypothesis (i.e., correlation = 0) as evidence for the null. Instead, a Bayesian approach is needed to compare the support of the data for the null versus the alternative (i.e., correlation > 0) hypothesis. Second, the often low reliabilities of the performance and awareness measures can attenuate the correlation, making a positive correlation appear to be zero. Hence, the correlation must be inferred in a way that disattenuates the weakening effect of measurement (trial) error. We apply two Bayesian models that account for measurement error to the Salvador et al. data. The results provide at best anecdotal support for the claimed unconscious nature of participants' memory-suppression performance. Researchers are urged to employ Bayesian methods that account for measurement error to analyze correlational data involving measures of performance and awareness rather than NHST methods.

A practical perspective on knowledge space theory: ALEKS and its data

CS

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McGraw-Hill Education

The ALEKS (Assessment and LEarning in Knowledge Spaces) educational software system is an instantiation of knowledge space theory (KST) that has been used by millions of students in mathematics, chemistry, statistics and accounting. The software employs a probabilistic assessment based on KST for placement into an appropriate course or curriculum, a learning mode in which students are guided through course material according to a knowledge structure, and regularly spaced re-assessments which are also based on KST. In each of these aspects, the interactions of the student with the system are guided by the theory and by insights learned from student data. We present several relationships between theory and data for the ALEKS system. We begin by surveying the ALEKS system and examining some practical aspects of implementing KST on a large scale. We then study the

effectiveness of the ALEKS assessment using both standard statistical measures and ones adapted to the KST context. Finally, we examine the learning process in ALEKS via statistics for the learning mode and its associated knowledge structures.

Structural Parameter Interdependencies in Computational Models of Cognition

CS

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1: Columbia University; 2: Max Planck Institute for Human Development; 3: Karlsruhe Institute of Technology

Computational modeling of cognition allows measurement of latent psychological variables by means of free model parameters. The estimation and interpretation of these variables is impaired, however, if parameters strongly correlate with each other. We suggest that strong parameter intercorrelations are especially likely to emerge in models that combine a subjective value function with a probabilistic choice rule—a common structure in the literature. We demonstrate high intercorrelation between parameters in the value function and the probabilistic choice rule across several prominent computational models, including models on risky choice (cumulative prospect theory), categorization (the generalized context model), and memory (the SIMPLE model of free recall). Based on simulation studies, we show that the presence of parameter intercorrelations hampers estimation accuracy, in particular the ability to detect group differences on the parameters and to detect associations of the parameters with external variables. We show that these problems can be alleviated by changing the models' error component, such as assuming parameter stochasticity or a constant error term. Our analyses highlight a common but often neglected problem of computational modeling of cognition and point to ways in which the design and application of such models can be improved.

Categorization

Attention constraints and learning in categories

CT

Bhui, Rahul (1); Jiao, Peiran (2)

1: Harvard University; 2: Maastricht University, Netherlands

Attention is often characterized as a means of uncertainty reduction, but the extent to which it is guided by structure in the environment remains unclear. Here, we investigate how the efficient use of limited attention can lead to a focus on information that applies commonly across members of a category. In three pre-registered experiments using mousetracking, we show that people change their patterns of attention as qualitatively predicted by rational principles. They preferentially sample category-level information when it is more variable, when time constraints are more severe, and when the category contains more members. However, their strategies fall quantitatively short of optimality, exhibiting a bias toward an even 1/N split over all information sources. We observe some signs of convergence toward the optimal strategy with experience, as well as curriculum learning effects. Our results help shed light on the ways in which rational principles account for attention allocation and provide novel evidence about the drivers of categorical thinking.

REFRESH: A New Approach to Modeling Dimensional Biases in Perceptual Similarity and Categorization

CT

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1: University of Warwick, United Kingdom; 2: Duke University, USA; 3: University of Wisconsin-Madison, USA; 4: Warwick Business School, United Kingdom

Much categorization behavior can be explained by family resemblance: new items are classified by comparison with previously learned exemplars. However, categorization behavior also shows dimensional biases, where the underlying space has so-called “separable” dimensions: ease of learning categories depends on how the stimuli align with the separable dimensions of the space. For example, if a set of objects of various sizes and colors can be accurately categorized using a single separable dimension (e.g., size), then category learning will be fast, while if the category is determined by both dimensions, learning will be slow. To capture these dimensional biases, models of categorization supplement family resemblance with either rule-based systems or selective attention to separable dimensions. But these models do not explain how separable dimensions initially arise; they are merely treated as unexplained psychological primitives. We develop, instead, a pure family resemblance version of the Rational Model of Categorization, which we term the Rational Exclusively Family RESemblance Hierarchy (REFRESH), which does not presuppose any separable dimensions. REFRESH infers how the stimuli are clustered, and uses a hierarchical prior to learn expectations about the location and variability of clusters across categories. We first demonstrate the dimensional-alignment of

natural category features and then show how through a lifetime of categorization experience REFRESH will learn prior expectations that clusters of stimuli will align with separable dimensions. REFRESH captures the key dimensional biases, but also explains their stimulus-dependence and specific learning effects, properties that are difficult to explain with rule-based or selective attention models.

An observer model version of general recognition theory

CT

Soto, Fabian

Florida International University

Many research questions involve determining whether two stimulus properties are represented "independently" or "invariantly" versus "configurally" or "holistically." General recognition theory (GRT) provides formal definitions of such concepts and dissociates perceptual from decisional forms of independence. Two issues with GRT are (1) the arbitrariness of the dimensional space in which the model is defined, and (2) that it provides insight on whether dimensions interact, but not on how they interact. Here, we link GRT to the linear-nonlinear observer model underlying classification image techniques. This model is defined in a non-arbitrary stimulus space, and facilitates studying how sampling of information from that space (summarized in classification images) contributes to dimensional interactions. We define template separability as a form of independence at the level of the perceptual templates assumed by this model, and link it to perceptual separability from the traditional GRT. Their theoretical relations reveal that some violations of perceptual separability may be due to the stimuli used rather than a property of the observer model. Naturalistic stimuli, such as faces, readily produce patterns of interactivity in a GRT model even when there is no perceptual interaction in the underlying observer model. Stimulus factors can also account for reports of unexpected violations of separability found in the literature (e.g., between line orientation and size). In addition, perceptual separability can be observed even when there is no underlying template separability in the observer model. This means that invariance/separability learning may be the product of adaptive modification of non-invariant representations.

Contrast as supervision in process models of classification behavior

CT

Wimsatt, Jay; Vigo, Ronaldo

Ohio University

In this presentation we analyze three probabilistic models of classification behavior in terms of implicit assumptions involving contrast information. We show how, for different contrast sets, the models display inconsistencies from the standpoint of the empirical evidence. We conclude that their reliance on tacit assumptions for computing classical probabilities limit their explanatory capacity in as much as they cannot account for situations for which contrast cue information is not necessary. Furthermore, we provide empirical and theoretical evidence that such situations are more prominent in concept learning and classification behavior than previously realized.

Applications of the Bias-Variance Decomposition to Human Forecasting

CT

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Forecasts are generated by both human experts and statistical models, and their forecast accuracy can be understood using error decompositions. However, the assumptions that underlie decompositions used in the analysis of human error differ substantially from those used in the analysis of models. The lens model, one of the most popular error decompositions for human errors, treats the beliefs of the human forecaster as fixed parameters to be estimated. Modern decompositions of model error treat the model as a random result from the process of fitting to noisy data. We highlight how these different approaches can be combined, expanding the application of the lens model to groups and opening up new perspectives on the study of human forecasting. We argue that treating human beliefs as the result of a process of learning from noisy data (even without specifying that process) can help to explain many documented phenomena in the world of forecasting such as: what kinds of environments human judgment will have difficulty with and what kinds they will be successful in; what conditions underlie the success of bootstrapping and aggregation of independent forecasts. Just as understanding statistical models as random variables has helped to improve the understanding of error in statistics and machines learning, we believe this framework will be able to help guide the literature on human judgment to a better understanding of error, its determinants and the mechanisms capable of improving forecasting accuracy.

Constraints on continuous models applied to binary and multi-alternative choice

CT

Kvam, Peter

University of Florida

Models of continuous response tasks have been gainfully applied across a variety of perceptual and preferential choice paradigms. One benefit of these approaches is that they can serve as a general case of binary and multi-alternative choice models by dividing the continuum of evidence they produce into discrete regions corresponding to separate responses. Using these more general approaches elucidates "hidden" mechanisms of binary and multiple choice models that are often built into drift rates, thresholds, or parameter variability. In this talk, I present three empirical phenomena related to these hidden mechanisms, examining the constraints that they place on continuous models being applied to multi-alternative and binary choice. First, different choice options should be able to have different stopping rules (thresholds) based on their degree of similarity to other alternatives in the choice set.

Second, continuous models must contain different mechanisms for different "drift rate" manipulations such as stimulus coherence, stimulus-response match, and the discriminability (confusability) of different response options. And third, continuous models must be able to store evidence for response options that are outside the initial choice set and map it onto new response options when they appear during a trial. Each of these constraints is imposed by an empirical phenomenon: participants in three experiments showed greater accuracy and faster response times for dissimilar response alternatives in a set; diverging effects of discriminability, coherence, and match manipulations; and efficient re-mapping of evidence when new choice options were introduced partway through an experimental trial.

Deep Generative Models as perceptual front-ends for decision-making

CT

Montero, Milton Llera; Costa, Rui Ponte; Bowers, Jeff; Ludwig, Casimir; Malhotra, Gaurav

University of Bristol, United Kingdom

Evidence integration models such as the Drift-diffusion model (DDM) are extremely successful in accounting for reaction time distributions and error rates in decision making. However, these models do not explain how evidence, represented by the drift, is extracted from the stimuli. Models of low-level vision, such as template-matching models, propose mechanisms by which evidence is generated but do not account for RT distributions. We propose a model of the perceptual front-end, implemented as Deep Generative Model, that learns to represent visual inputs in a low-dimensional latent space. Evidence in favour of different choices can be gathered by sampling from these latent variables and feeding them to an integration-to-threshold model. Under some weak assumptions this architecture implements an SPRT test. Therefore, it can be used to provide an end-to-end computational account of reaction-time distributions as well as error-rates. In contrast to DDMs, this model can explain how drift and diffusion rates arise rather than infer them from behavioural data. We show how to generate predictions using this model for perceptual decisions in visual noise and how these depend on different architectural constraints and the learning history. The model thus provides both an explanation of how evidence is generated from any given input and how architectural constraints and learning affect this process. These effects can then be measured through the observed error rates and reaction-time distributions. We expect this approach to allow us to bridge the gap between the complementary, yet rarely interacting literature of decision-making, visual perceptual learning and low-level vision/psychophysics.

Data-driven Modeling of Delay Discounting Identifies Novel Discounting Behavior

CT

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Delay discounting is a preferential choice task that measures the rate at which individuals discount future rewards. Many models that have been proposed for this task fail to describe the full range of behavior that can be exhibited by participants. One reason for this is that most models assume a simple monotonic relationship in which future rewards are discounted as the delay increases. The lack of flexibility of these models can potentially expose experiments to biases introduced by model misspecification. Addressing this problem, we propose a nonparametric Bayesian approach (Gaussian Process with active learning: GPAL), for modeling delay discounting. A Gaussian Process model is fit to data while simultaneously selecting highly informative experimental designs in each trial based on responses from earlier trials. Results show that GPAL is an efficient and reliable framework that is capable of capturing patterns that prominent models are insensitive to. In particular, we identified two of these patterns that were systematically observed in our data and analyze them in detail. These patterns reveal properties that violate common normative assumptions made by virtually all parametric models of discounting and therefore have been rarely discussed in the literature. We offer possible explanations that could account for these abnormal choice behaviors and propose enhancements to existing parametric models motivated by these explanations.

Memory

Understanding Memory for WHERE using Smartphone Data

CT

Dennis, Simon; Laliberte, Elizabeth; Yim, Hyungwook; Stone, Benjamin

University of Melbourne

In 1984, Ronald Cotton was convicted for rape and burglary. He was sentenced to life + 50 years. In 1995, he was released having served over 10 years in prison. When Cotton was interrogated he provided a false alibi. Rather than report where he had been at the time of the crime, Cotton recalled where he had been the week before. A primary challenge for alibi generation research is establishing the ground truth of the real world events of interest. We used a smartphone app to record data on participants ($N = 57$) for a month prior to a memory test. The app captured their accelerometry continuously and their GPS location and sound environment every ten minutes. After a week retention interval, we presented participants with a series of trials which asked them to identify where they were at a given time from among four alternatives. Participants were incorrect 36% of the time (SD = 16%). Furthermore, our forced choice procedure allowed us to conduct a conditional logit analysis to assess the relative importance of different aspects of the events to the decision process. The Cotton example suggests that participants might also confuse days across weeks and we found strong evidence of this kind of error. In addition, people often confused weeks in general and also hours across days. Similarity of location induced more errors than similarity of sound environments or movement types.

The method of loci is an optimal policy for memory search

CT

Zhang, Qiong; Norman, Kenneth A.; Griffiths, Thomas L.

Princeton University

The method of loci is a powerful mnemonic technique for memorizing a list of unrelated items. With a pre-specified route in a familiar “memory palace”, one can encode material by attaching items to loci along this route, and later effectively recall them by mentally walking along the same route. Despite its efficacy, there is no existing model that explains why the method of loci promotes memory improvement during memory search. To fill this gap, we provide a rational account of why the method of loci improves memory. We define memory search as a task with the goal of minimizing retrieval cost, and demonstrate that the method of loci gives an optimal policy for this task. We discuss the implications of this result, and how it connects to the role of structural prior knowledge in facilitating new learning.

How Does Modern Life Affect Memory Retrieval: Analyzing News Headlines

CT

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University of Wisconsin-Madison

Technological advances are speeding up the pace of our lives. With this increasing pace, the rate at which the brain expects items should accelerate as well. How does technology affect memory retrieval? One theory suggests that human memory is adapted to the statistics of our environment (Anderson & Schooler, 1991). Environmental sources, such as newspaper headlines provide a reflection of the retrieval demands from human memory at different times. By analyzing changes in environmental statistics, such as the time-frequency of event occurrences, we tracked and analyzed how the environment affects memory. We focus on frequency and spacing effects, the latter of which is that the spacing between successive repetitions of an item affects how well the item is remembered at different times from the last occurrence. Working with headlines of The New York Times from 1919 to 2019, we captured changes in the spacing effect. We found that the recurring pattern is polarized between the most and least frequent words: popular words become more likely to recur, and uncommon words less likely. However, the overall recurring likelihood remains fairly constant. We fitted Hawkes' self-exciting point processes well on the data and were able to predict word recurrences with high accuracy.

Beyond Pattern Completion with Short-Term Plasticity

CT

Shabahang, Kevin; Yim, Hyungwook; Dennis, Simon

University of Melbourne

In a Linear Associative Net (LAN), all input settles to a single pattern, therefore Anderson, Silverstein, Ritz, and Jones (1977) introduced saturation to force the system to reach other steady-states in the Brain-State-in-a-Box (BSB). Unfortunately, the BSB is limited in its ability to generalize because its responses are restricted to previously stored patterns. We present simulations showing how a Dynamic-Eigen-Net (DEN), a LAN with Short-Term Plasticity (STP), overcomes the single-response limitation. Critically, a DEN also accommodates novel patterns by aligning them with encoded structure. We train a two-slot DEN on a text corpus, and provide an account of lexical decision and judgement-of-grammaticality (JOG) tasks showing how grammatical bi-grams yield stronger responses relative to ungrammatical bi-grams. Finally, we present a simulation showing how a DEN is sensitive to syntactic violations introduced in novel bi-grams. We propose DENs as associative nets with great.

A Bayesian Collaborative Filtering Approach to Alleviating the Cold Start Problem in Adaptive Fact Learning

CT

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University of Groningen, The Netherlands

We present a method for mitigating the cold start problem in a computer-based adaptive fact learning system. Currently, learning sessions have a "cold start": the learning system initially does not know the difficulty of the study material, resulting in a suboptimal start to learning.The fact learning system is based on a computational model of human memory and adaptively schedules the rehearsal of facts within a learning session. Facts are repeated whenever their activation drops below a threshold, ensuring that repetitions occur as far apart as possible, while still happening soon enough to encourage successful recall. Throughout the session, response times and accuracy are used to update fact-specific rate-of-forgetting estimates that determine each fact's decay, and thereby its repetition schedule. When a learner first studies a set of items, the memory model uses default rate-of-forgetting estimates, leading to a suboptimal rehearsal schedule at the start of the session: easy facts are initially repeated too much, while difficult facts are repeated too infrequently.Here, we take a collaborative filtering approach to reducing the cold start problem. A Bayesian model, trained on rate-of-forgetting estimates obtained from previous learners, predicts the difficulty of each fact for a new learner. These predictions are then used as the memory model's starting estimates in a new learning session.In a preregistered experiment (n = 197), we confirm that this method improves the scheduling of repetitions within a learning session, as shown by participants' higher response accuracy during the session and better retention of the studied facts afterwards.

Using cross-validation to evaluate model components: The case of visual working memory

CT

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University of Warwick, United Kingdom

Mathematical models are frequently used to formalize and test theories of psychological processes. When there are multiple competing models, the scientific question becomes one of model selection: How to select the model that most likely represents the underlying data-generating process? One common method is to select the model that strikes the best compromise between goodness of fit and complexity. For example, by penalizing model fit with the number of parameters (e.g. AIC, BIC). The idea of such an approach is that a model that fits the data well but is not too complex likely generalizes well to new data. A more direct approach of evaluating a model's ability to generalize to new data is using cross validation;

each model is repeatedly fit to a subset of data and the results of that fit are used to predict the subset of the data that was not used for fitting.We compared both methods of model selection in the domain of visual-working memory. The theoretical debates in this domain are reflected in the components of its formal models: guessing processes, item limits, the stability of memory across trials, etc. We selected a number of common model variations and compared them using both AIC (which is commonly used in the field) and three types of cross validation. Our results suggest that both methods largely lead to the same theoretical inferences about the nature of memory. However, numerical issues commonly occur when fitting more complex model variants which complicates model selection and inference.

Effects of Working Memory Load on Motor Force Learning: A computational account

CT

Lerch, Rachel A.; Sims, Chris R.

Rensselaer Polytechnic Institute

We explore a computationally rational account of human motor learning, according to which learners must navigate a trade-off between the performance of their learned motor control policy, and the policy's complexity as measured in information-theoretic terms. To test this theory we developed a novel motor learning task in which subjects had to learn a mapping between arbitrary visual stimuli and motor responses of varying target force. The task manipulates information processing demands on the learner by varying the set size of stimuli to which subjects had to learn the correct stimulus-action mapping. We utilize the mathematical framework of rate-distortion theory to develop a model of optimal task performance subject to information processing constraints. The empirical trade-off between maximizing performance and minimizing the complexity of the motor policy used by subjects was found to be in general, though not exact, agreement with the theoretical predictions of our model. Task performance generally increased monotonically with policy complexity, and was lower in the larger set size condition, as predicted by our computational model.Secondly, by fitting parameterized distributions to the continuous response data (force profiles applied to targets), we also evaluate factors that characterize the motor response distributions between set size conditions. We find significant differences among several factors, including the timeshifts and narrowness of the response profiles that may contribute to the observed differences in performance. Together this work aims to highlight methods that reveal the relationship between resource constraints on learning, with the intention of motivating new research directions.

Using neural-network classification accuracy to measure the sufficiency of inferred cognitive parameters

CT

Westfall, Holly Anne; Lee, Michael David

University of California, Irvine

Cognitive models allow for the measurement of latent variables that cannot be directly observed with behavioral data. A concern is whether the inferred cognitive parameters are sufficient or whether there is more to be learned from the rest of the data. We present an analysis of a clinical data set of Alzheimer's patients diagnosed with the Functional Assessment Staging Test (FAST), where higher FAST stages represent greater functional impairment. Participants completed three immediate and one delayed free recall task. We used a cognitive model to infer latent parameters related to primacy, the tendency to better recall words at the beginning of a list, and recency, the tendency to better recall words at the end of a list. We developed two multi-layer linear neural networks with the goal of classifying patients into FAST stages based on their free-recall performance. One neural network takes only the basic behavioral data of trial-by-trial accuracy on the free recall tasks as input while the other takes only the inferred cognitive model parameters of primacy and recency for each list as input. We present a comparison of the relative cross-validation accuracy of the two neural networks to determine to what extent the model parameters capture the information about FAST stages that is provided by the behavioral data.

Flexibility in reaction time analysis: Many roads to a false positive?

CT

Morís Fernández, Luis (1,2); Vadillo, Miguel (1)

1: Universidad Autónoma de Madrid, Spain; 2: Universidad Pompeu Fabra, Barcelona

In the present talk, we explore the influence of undisclosed flexibility in the analysis of reaction times (RTs). RTs entail some degrees of freedom of their own, due to their skewed distribution, the potential presence of outliers and the availability of different methods to deal with these issues. Moreover, these degrees of freedom are usually not considered part of the analysis itself, but preprocessing steps that are contingent on data. We analysed the impact of these degrees of freedom on the false-positive rate using Monte Carlo simulations over real and simulated data. When several preprocessing methods are used in combination, the false-positive rate can easily rise to 17%. This figure becomes more concerning if we consider that more degrees of freedom are awaiting down the analysis pipeline, potentially making the final false-positive rate much higher. We propose that pre-registering studies would ameloriate this problem by reducing the degrees of freedom when analyzing RT data.

Type I error in diffusion models: A drift towards false positives?

CT

Morís, Joaquín; Morís Fernández, Luis; Vadillo, Miguel

Autonomous University of Madrid, Spain

Diffusion models are one of the most used tools to analyze reaction times (RT), and their relevance keeps growing overtime. According to these models, evidence is accumulated over time, until a threshold is reached, leading to a response. Contrary to simpler RT analysis approaches, these models are equipped with more parameters to be estimated, such as the drift rate, the threshold or non-decisional factors. This allows a more nuanced understanding of the process underlying the decision and response. Unfortunately, this higher number of parameters can also be problematic. We present a series of three simulations with Ratcliff's diffusion model. Simulation 1 used empirical data, Simulation 2 simulated data based on empirically estimated parameters and Simulation 3 was carried out with simulated data based on common distributions of the parameters. The three simulations show that commonly used statistical analyses in diffusion models can lead to an inflation of the Type I error rate. Different strategies to prevent this problem are discussed, including pre-registration of the analysis, model comparisons and Type I error corrections.

Foundational Challenges for Mathematical and Computational Cognitive Modeling in the 21st Century

CT

Vigo, Ronaldo

Ohio University

The emergence of machine learning as a computationally intensive approach to analyzing and discovering patterns in data has brought attention to aspects of mathematical modeling in cognitive science and psychology that have been, for the most part, previously ignored. In this talk, I discuss a handful of general mathematical modeling constructs, principles and problems that should be considered by those attempting to construct formal models of cognitive phenomena. These include the meaningfulness/soundness and completeness problem in modeling, the tractability of algorithms, the problem of parameter estimation in "deep learning" neural networks, the adequate testing of the predictive and explanatory power of models, and others. The goal is to demonstrate how modelers may enrich their toolbox of mathematical structures/constructs while improving the robustness, validity and reliability of their models.

On bias, signal detection, and sequential sampling

CT

Brandtzæg, Ørjan Røkkum; Biegler, Robert

Norwegian University of Science and Technology

We aim to address two issues. First, empirical work on how payoff asymmetries can bias decisions has used the total number of false positives compared to the total number of false negatives as a criterion. We explain why and when this criterion dissociates from bias c such that one criterion can indicate a liberal bias while the other indicates a conservative bias. Second, what is the optimal decision criterion in a sequential sampling problem, in which noise can be reduced by increased sampling, but at a cost? We derive a function for the cost of sampling, and use that to find the optimal sampling effort for a range of parameters. We will examine both using the case of male sexual overperception, the tendency of men to either believe or to act as if women are more interested in sex than is actually the case. The argument generalises to other examples of decisions under asymmetric payoffs.

Prediction Error and Surprise

CT

Lisøy, Rebekka Solvik (1); Pfuhl, Gerit (2); Biegler, Robert (1)

1: Norwegian University of Science and Technology; 2: University of Tromsø – The Arctic University of Norway, Norway

Prediction is one of the fundamental functions of the brain. Prediction allows the organism to prepare for events and direct attention to what is important: the unexpected, surprising and unknown. An event can only be identified as unexpected if there is an expectation or prediction to begin with, and if there is a large enough

deviation from that prediction. Because there is random variation in events themselves, in the perception of events, and in their prediction, "large enough" can only be a statistical judgement. If either the criterion for what is surprising is inappropriate, or if the estimate of prediction error is systematically wrong, then the balance between type I and type II errors shifts. Excessive surprise caused by overestimation of prediction error has been proposed to be a cause of both psychosis and autism (Fletcher & Frith, 2009; Frith, 2005; van de Cruys et al., 2014). The question of whether the criterion for surprise might contribute has received little attention. In a simulation, we varied both the misestimation of prediction error and the criterion for surprise by the same factor, and calculated how often individuals with varying criteria and degrees of misestimation are surprised. We find that the criterion for surprise has a greater influence on the proportion of surprises than misestimation of prediction error. Evaluation of computational theories of psychosis and autism depends on developing experimental designs that can distinguish these factors.

Recognition Memory

A systematic re-examination of the list-length effect in recognition memory

CT

Yim, Hyungwook; Osth, Adam; Dennis, Simon

The University of Melbourne

The list-length effect (LLE) in recognition memory refers to the phenomenon where performance decreases as the length of the to-be-remembered list increases. The phenomenon has been theoretically important in the literature concerning the sources of forgetting since the existence of the LLE entails that memory interference stems from each individual item (i.e., item-noise) compared to other sources such as interference from pre-experimental experience (i.e., context noise). Regarding the existence of the LLE, Brandt et al. (2019) recently showed that the experimental designs that support a null LLE suffer from confounds regarding the ordering of experimental conditions (i.e., using a counterbalanced within-subjects design). Therefore, with new evidence for a LLE, in the current study, we re-examined the LLE more systematically manipulating different list-length, delay-length, stimuli-type, and study-time (60 conditions), and using a between-subjects design with a large sample size via mTurk (3,600 participants, 60 participants per condition). Results show evidence for a LLE with different amount of interference across different stimulus type and conditions, which supports that item-noise affects recognition memory. Additionally, we utilized a computational model (Osth & Dennis, 2015) to compare the relative amount of interference (e.g., item-noise, context-noise) affecting recognition memory across conditions. We find that although item-noise exists, there is a greater contribution of context-noise in recognition memory.

Does source memory exist for unrecognized items?

CT

Fox, Julian William; Osth, Adam

The University of Melbourne

In episodic memory research, there is a debate concerning whether decision-making in recognition and source memory is better explained by models that assume discrete cognitive states, or continuous underlying strengths. One aspect in which these classes of models differ is their predictions regarding the ability to retrieve contextual details (or source details) of an experienced event, given that the event itself is not recognized. Discrete state models predict that when items are unrecognized, source retrieval is not possible and only guess responses can be elicited. In contrast, models assuming continuous strengths predict that it is possible to retrieve the source of unrecognized items (albeit with low accuracy). Empirically, there have been numerous studies reporting either chance accuracy or above-chance accuracy for source memory in the absence of recognition. For instance, studies presenting recognition and source judgments for the same item in immediate succession have revealed chance-level accuracy, while studies presenting a block of recognition judgments followed by a block of source judgments have revealed slightly above-chance accuracy. In the present investigation, data from two novel experiments involving multiple design manipulations were investigated using a hierarchical Bayesian signal detection model. Across most conditions it was shown that source accuracy for unrecognized items was slightly above chance. It is suggested that findings of a null effect in the prior literature may be attributable to design elements that hinder source memory as a whole, and to high degrees of uncertainty in the participant-level source data when conditioned on unrecognized items.

Adaptive Design for General Recognition Theory Experiments

CT

Glavan, Joseph (1,2,3); Havig, Paul (2); Mohd-Zaid, Fairul (2); Houpt, Joseph (1)

1: Wright State University, Dayton, Ohio; 2: Air Force Research Laboratory, Wright-Patterson AFB, Ohio; 3: Consortium of Universities of the Washington Metropolitan Area, Washington, D.C.

General recognition theory (GRT), a multivariate generalization of signal detection theory, is a powerful means for inferring the interaction of representations and decision processes when perceiving a multidimensional stimulus. In order for inferences to be made from a GRT experiment, stimuli must be sufficiently confusable so that subjects make identification errors. Stimulus intensities are typically chosen through repeated pilot testing, and the same stimuli are used for every subject in the experiment. This approach is time consuming on its own but can critically fail for some subjects due to individual differences. Here, we propose an algorithm to improve the effectiveness of GRT by adapting the design of the experiment to individual subjects. Our method leverages adaptive psychophysical methods (e.g., Psi, Quest+) to iteratively fit a highly constrained GRT model to a subject's responses in real time. The algorithm converges rapidly on a rough approximation of the subject's internal

perceptual process by assuming perceptual independence, perceptual separability, and decisional separability. The user only needs to specify the intensity range of interest for each perceptual dimension of the stimulus for the adaptive process to generate reasonable stimuli to use in the main GRT experiment. When combined with the analysis code provided by existing R packages, our method permits a completely automated pipeline from hypothesis to data collection to statistical inference. We present the results from a simulation study assessing the recoverability and statistical properties of the algorithm and one human experiment comparing the adaptive process to the more traditional pilot testing approach.

Integrating word-form representations with global similarity computation in recognition memory

CT

Osth, Adam

The University of Melbourne

It has been well established in recognition memory paradigms that participants exhibit higher probabilities of falsely endorsing lures that are perceptually similar to the studied words. Recognition memory models explain this phenomenon as a consequence of global similarity computation – choice probability is proportional to the aggregated similarity between the probe word and each of the study list words. However, to date such models have not integrated perceptual representations of the words themselves. In this work, I explore the consequences of a variety of word-form representations from the psycholinguistics of reading literature. These include representations where similarity is a function of the number of in-position letter matches (slot codes and both edges representation), representations with noisy position codes (the overlap model; Gomez, Ratcliff, & Perea, 2008), along with matches based on relative position matches (bigram models). Global similarity among the representations was linked to choice and response times using the linear ballistic accumulator model (Brown & Heathcote, 2008). Results demonstrated (a) a general superiority of bigram models, (b) changes in perceptual representations under shallow processing, and (c) comparable interference from perceptual similarity as semantic similarity, where semantic similarity was calculated using Word2Vec representations (Mikolov et al., 2013).

Decomposing categorical and item-specific preferences using sequential sampling models

CT

Desai, Nitisha (1); Krajbich, Ian (1,2)

1: Department of Psychology, The Ohio State University; 2: Department of Economics, The Ohio State University

Value-based decision making can be complex because many factors influence choices. For example, one might choose Item A over Item B because As are generally better, because As come with a bonus, or because you get more of A than of B. These factors would all manifest as increased choice probabilities for As over Bs despite arising from different considerations. Here, we use the diffusion model (HDDM) to identify patterns associated with these different kinds of biases, namely response, stimulus, and magnitude biases.In two experiments, subjects ($n_1 = 67$, $n_2 = 89$) first rated how much they would like to eat various snack foods, then made binary choices between those foods. We randomly designated options on one side of the screen as the targets. Our conditions were as follows: (1) Proportion – the target side had higher value foods a majority of the time; (2) Quarter – the target side came with a 25-cent bonus; (3) Double – the target side had twice as much food; (4) Demand – we told subjects that we were testing if people favor options on the target side. Our results revealed an overall response bias in the Proportion condition, but not in the Demand condition; a stimulus bias in the Quarter condition; and a magnitude bias in the Double condition. We also investigated how response biases develop and disappear over time. In conditions where the target side was consistently better, starting-point biases increased over time; in conditions where the target and non-target side were equally attractive, starting-point biases decreased over time.

Confidence as a Continuous State of Evidence with Dynamic Competition

CT

Yi, Woojong (1); Davelaar, Eddy J. (2); Usher, Marius (3); Turner, Brandon (1)

1: The Ohio State University; 2: Birkbeck, University of London, UK; 3: Tel-Aviv University, Israel

For a long time, choice and response time (choice-RT) have been the central behavioral measures used to explore the mechanism of choice. In addition to choice-RT, confidence has also been considered as a measure of behavioral judgment. Recently, many researchers have attempted to integrate those behavioral measures (choice, response time, and confidence) into the unified modeling framework (Poisson Race Model: Merkle & Van Zandt, 2006; RTCON: Ratcliff & Starns, 2009; 2DSD: Pleskac & Busemeyer, 2010). Here, we propose a way of modeling confidence with the leaky, competing, accumulator (LCA; Usher & McClelland, 2001). To do so, we rely on a simple solution to mapping the continuous states of evidence in the LCA with the relative balance of evidence hypothesis (Vickers, 1979). The competitive nature of

the accumulation process in the LCA framework can produce continuous decision states, as an asymptotic accumulation and have different effects on accuracy, RT, and of course, confidence. In this study, we will investigate how the LCA can be accompanied by confidence and how the dynamic competitions between the accumulators with information leakage and lateral inhibition can affect confidence as a continuous state of the evidence. Simulation results show that the LCA can successfully account for all the main benchmarks of confidence modeling (Pleskac & Busemeyer, 2010).

Attentional dynamics in multi-attribute preferential choices

CT

Yang, Xiaozhi; Krajbich, Ian

The Ohio State University

When making decisions, how people allocate their attention influences their choices. One empirical finding is that people are more likely to choose the option that they have looked at more. This relation has been formalized with the attentional drift-diffusion model (aDDM; Krajbich et al., 2010). However, options often have multiple attributes. Attention is also thought to govern the relative weighting of those attributes (Roe et al. 2001). However, little is known about how these two distinct features of the choice process interact; we still lack a model (and tests of that model) that incorporate both option and attribute-wise attention. Here, we propose a multi-attribute attentional drift-diffusion model to account for attentional discount factors on both options and attributes. We then use five eye-tracking data sets (two-alternative, two-attribute preferential tasks) from different choice domains to test the model. We find very stable option-level and attribute-level attentional discount factors across data sets, though non-fixated options are consistently discounted more than non-fixated attributes. Additionally, we find that people generally discount the non-fixated attribute of the non-fixated option in a multiplicative way, and so that feature is consistently discounted the most. Finally, we also find that gaze allocation reflects attribute weights, with more gaze to higher-weighted attributes. In summary, our work uncovers an intricate interplay between attribute weights, gaze processes, and preferential choice.

Explicit value cues and response caution in value-based decisions

CT

Shevlin, Blair (1); Smith, Stephanie M. (2); Hausfeld, Jan (3); Krajbich, Ian (1)

1: The Ohio State University; 2: University of California, Los Angeles; 3: Universität Konstanz, Germany

All else being equal, preference-based choices become faster as the values of the alternatives increase, a phenomenon we refer to as the overall-value effect. There are many competing explanations for the overall-value effect, with normative, mechanistic, and artefactual origins. Here, we examined these potential explanations, applying diffusion modeling to choice and response-time (RT) data from three difference choice domains (snack foods, abstract art, and conditioned stimuli). Within each experiment, we manipulated whether subjects knew the range of overall val-

ues in the upcoming block of trials. In each experiment, when subjects did not know the value of the upcoming trials, we observed the overall-value effect. The presence of the overall-value effect in the conditioned-stimulus experiment indicates that it is not due to artefacts from how we measure value, nor from familiarity with high-value items. Moreover, in most cases we also observed accuracy increasing with overall value, which rules out many of the mechanistic, noise-based explanations. When subjects knew the value of the upcoming trials, their response caution (i.e., boundary separation in the diffusion model) increased for high-value trials compared to middle-value trials, reflecting longer RT. This indicates that the overall-value effect is not normative since value-informed subjects display a reverse overall-value effect. Our results indicate that the overall-value effect is a robust phenomenon and is best explained as stronger evidence (i.e. higher drift rates) for higher value items.

To Maximize Gains or to Minimize Losses?

CT

Schramm, Pele; Yechiam, Eldad

Technion, Israel Institute of Technology, Israel

In a repeated decisions task, subjects were asked to choose between minimizing their chances of losses and maximizing their chances of gains. After each trial, both losses and gains were simultaneously reported (even if 0). The probabilities of losses and gains were manipulated by the choices of the participants such that the expected value of net earnings was 0 regardless of choice, but negative if participants failed to make a choice in time. Multiple iterations of the study were conducted, manipulating factors such as payoff magnitudes, probabilities, and time limit. In addition to the primary task, additional measures were included as covariates such as for loss-aversion and behavioral approach/inhibition (BIS/BAS). Participants were compensated monetarily for their time by an amount partially dictated by their task earnings. The talk will overview the changing patterns of responses over the course of the task for the different conditions and their connection to the measured covariates.

Statistics

Using parameter contours to achieve more robust model estimation

CT

Sloman, Sabina Johanna; Broomell, Stephen; Oppenheimer, Daniel

Carnegie Mellon University

Many current practices in parameter estimation and model evaluation rely on fit statistics, calculated on the basis of estimated parameterizations of competing models. However, the design of an experiment can influence the conclusions a modeler draws about the parameterizations and relative performance of these models (Broomell, Sloman, Blaha, & Chelen, 2019). We highlight the importance of mapping the model-stimulus space, i.e. understanding how the parameter-dependent predictions of a model change across different stimuli. To achieve this goal, we represent models as a topography across the stimulus space, in which adjacent contour lines are defined by adjacent parameter values. Using data simulated from models of decision-making, we show how our proposed techniques can identify conditions under which traditional parameter estimation techniques will lead to inconclusive and inconsistent results. We also discuss ways in which modelers could exploit these insights to develop experimental designs for more robust parameter estimation. In addition, we demonstrate how a better understanding of the model-stimulus space can help researchers design powerful experiments to diagnose data generated by hypothesized models. Finally, we explore the conceptual implications of representing cognitive models as a topography of the stimulus space.

A hierarchical Bayesian model for the progressive ratio test

CT

Chen, Yiyang; Breitborde, Nicholas; Peruggia, Mario; Van Zandt, Trisha

The Ohio State University

The progressive ratio test (Wolf et al., 2014) is commonly used to measure motivation, yet the number of studies investigating its underlying mechanisms is limited. In this paper, we present a hierarchical Bayesian model for the progressive ratio structure. This model may be used to investigate the underlying mechanisms of human behavior in progressive ratio tests, which can identify the factors contributing to participants' performance. A simulation study shows satisfactory parameter recovery results for this model. We apply the model to a progressive ratio data set involving people with schizophrenia, first-order relatives of the schizophrenia patients, and people without schizophrenia. Analysis reveals that the motivation of people with schizophrenia decreases faster as time elapses than that of people without schizophrenia, which may make them less compliant with long continuous treatment sessions.

A robust Bayesian test for context effects in multi-attribute decision making

CT

Katsimpokis, Dimitris; Fontanesi, Laura; Rieskamp, Jörg

University of Basel, Switzerland

In the past decades, context effects have been crucial in the development of cognitive models of decisions between multi-attribute alternatives. Nevertheless, to this date, only few studies have discussed what the best practices to analyze context effects are. Context effects occur when participants prefer identical options more or less depending on the choice set they are embedded in. Context effects are measured using what is called the Relative choice Share of the Target (RST), i.e., the change in preference of a target option from one choice set to the next. In this talk, we discuss two ways of calculating the RST: one frequently used in the literature, and a novel one we propose. Through simulations, we show that our proposed RST analyses overcome shortcomings of the more traditional approach. In particular, it is resistant to biases due to unequal sample size across choice sets. Furthermore, we apply our model to four previously published context effect studies, and we show that some reported context effects can change substantially (from significant to non-significant and vice versa). Implications of these results for cognitive modeling and empirical research on context effects are further discussed.

stanova: User-Friendly Interface and Summaries for Bayesian Statistical Models Estimated with Stan

CT

Singmann, Henrik

University of Warwick, United Kingdom

Psychological data often consists of multiple orthogonal factors. When analyzing such data with statistical models these factors, like all categorical variables, need to be transformed into numerical covariates using a contrast scheme. To the surprise of many users, the default contrast scheme in the statistical programming language R is such that the intercept is mapped onto the first factor level with the consequence that in models with interactions, coefficients represent simple effects at the first factor level instead of the usually expected average effects. I will present a software package for R, stanova (https://github.com/bayesstuff/stanova), that allows estimating statistical models in a Bayesian framework based on Stan and package rstanarm that avoids this problem. It by default uses a factor coding proposed by Rouder et al. (2012, JMP) in which the intercept corresponds to the unweighted grand mean and which allows priors that have the same marginal prior on all factor levels. In addition, stanova provides a summary method which reports results for each factor level or design cell – specifically the difference from the intercept – instead of for each model coefficient. This also provides a better user experience than the default output of many statistical packages. The talk will show the implementation of the package in R and its adaptation in JASP, an open source alternative to SPSS.

Prior predictive entropy as a measure of model complexity

CT

Villarreal, Jesus Manuel; Lee, Michael David; Etz, Alex

University of California, Irvine

In science, when we are faced with the problem of choosing between two different accounts of a phenomenon, we are told to choose the simplest one. However, it is not always clear what a "simple" model is. Model selection criteria (*e.g.*, the BIC) typically define model complexity as a function of the number of parameters in a model, or some other function of the parameter space. Here we present an alternative based on the prior predictive distribution. We argue that we can measure the complexity of a model by the entropy of its predictions before looking at the data. This can lead to surprising findings that are not well explained by thinking of model complexity in terms of parameter spaces. In particular, we use a simple choice rule as an example to show that the predictions of a nested model can have a higher entropy in comparison to its more general counterpart. Finally, we show that the complexity in a model's predictions is a function of the experimental design.

Lord's Paradox: Why science should govern statistics, not the reverse

CT

Shiffrin, Richard

Indiana University

In 1967 Frederic Lord published a two page paper on weight changes over time by two groups. A scientist would surely conclude that the data show individuals in both groups were fluctuating in weight but not gaining or losing. Yet an analysis of covariance (ANCOVA) seemed to lead to a conclusion that the initially heavier group was gaining more than the initially lighter group. Lord seemed to present this as an example showing that inappropriate use of ANCOVA leads to absurd conclusions, yet statisticians and causal modelers have been re-examining this paradox ever since, sometimes concluding that one cannot reach a valid conclusion, sometimes concluding that the correct conclusion is more weight gain for the initially heavier group. I use this example to highlight the importance of using science to guide the way we do statistics, rather than using statistics to tell us how to do science. More generally, I wish to highlight the value in generating plausible, simple, and coherent models for observed data.

Prior predictive entropy as a measure of model complexity

CT

Rouder, Jeffrey (1); Haaf, Julia (2)

1: University of California, Irvine; 2: University of Amsterdam

The importance of good model specification — having models that accurately capture differing theoretical position — cannot be understated. With this in mind, we submit that methods of inference that force scientists to use certain models that

may not be appropriate for the context are not as desirable as methods with no such constraint. Here we ask how posterior-predictive model assessment methods such as wAIC and LOO-CV perform when theoretical positions are different space restrictions on a common parameter space. One of the main theoretical relations is nesting — where the parameter space of one model is a subset of that for another. A good example is a general model that admits any set of preferences; a nested model is one that admits only preferences that obey transitivity. We find however, that posterior-predictive methods fail in these cases providing no advantage to more constrained models even when data are compatible with the constraint. Researchers who use posterior predictive methods are forced to use non-overlapping partitions of parameter spaces even some of subspaces have no theoretical interpretation. Fortunately, there is no constraint of prior predictive methods such as Bayes factors. Because these model appropriately account for model complexity, models need not be a proper partitioning of parameter spaces and inference with desirable properties nonetheless results. We argue given that posterior predictive approaches forces certain specifications that may not be ideal for scientific questions, they are less desirable in these contexts.

Reaction Time Analysis

Testing the race model in a difficult redundant signals task

CT

Gondan, Matthias; Dupont, Dawa; Blurton, Steven

University of Copenhagen, Denmark

In the redundant signals task, participants respond, in the same way, to stimuli of several sources, which are presented either alone or in combination (redundant signals). The responses to the redundant signals are typically much faster than to the single signals. Several models explain this effect, including race and coactivation models of information processing. Race models assume separate channels for the two components of a redundant signal, with the response time determined by the faster of the two channels. Because the slower processing times in one channel are canceled out by faster processing in the other channel, responses to redundant signals are, on average, faster than to single signals. In contrast, coactivation models relate the redundancy gain to some kind of integrated processing of the redundant information. The two models can be distinguished using the race model inequality (Miller, 1982) on the response time distribution functions. Miller's prediction was derived for experiments with 100% accuracy, and despite corrections for guesses and omitted responses, it is limited to easy tasks with negligible error rates. We generalize Miller's inequality to non-trivial experimental tasks in which incorrect responses may occur systematically. The method is illustrated using data from difficult discrimination tasks with Go/Nogo and choice responses. More than 150 years after Donders' (1868) first response time experiment, the present study shows that it is possible to run response time tasks at any difficulty—if the appropriate analysis technique is chosen.

Effects of frustration of the achievement motive on task processing: Findings from diffusion model analyses

CT

Lerche, Veronika

Heidelberg University, Germany

In motive research, the analysis of experimental data by means of mathematical models like the diffusion model is not yet a common approach. Based on the results of two studies (N1 = 108, N2 = 104), I demonstrate that the diffusion model (Ratcliff, 1978) is a useful tool to gain more insights into motivational processes. The experiments were inspired by findings of a study by Brunstein and Hoyer (2002). They observed that individuals high in the implicit achievement motive who receive negative intraindividual performance feedback speed up in a response time task. The reduced mean response times were interpreted in terms of an increase in effort. In the two studies, in which I used a similar feedback manipulation, individuals with high implicit achievement motive decreased their threshold separation parameter. Thus, they became less cautious over the time working on the task. Accordingly, the decrease in response times previously reported might mainly be attributable to a change in strategy (focusing on speed instead of accuracy) rather than to an increase in effort. The results will be discussed in the context of emotion regulation strategies.

The associative property holds for combination of auditory, visual, and tactile signals in multisensory decisions

CT

Otto, Thomas U.

University of St Andrews, United Kingdom

A prominent finding in multisensory research is that reaction times (RTs) are faster to bimodal signals compared to the unimodal components, which is the redundant signals effect (RSE). An intriguing explanation of the effect comes with race models, which assume that responses to bimodal signals are triggered by the faster of two parallel decision units, which can be implemented by a logic OR-gate. This basic model architecture results in statistical facilitation and the RSE can be predicted based on unisensory RT distributions and probability summation. To test the explanatory power of the framework, an expansion of the bimodal RSE is that RTs to trimodal signals are even faster. To measure the effect, I presented three unimodal signals (in vision, audition, and touch), all bimodal combinations, and a trimodal condition. To adapt the model, a corresponding extension simply assumes that responses are triggered by the fastest of three parallel decision units. Following the associative property in mathematics, an interesting proposition is that probability summation with any bimodal and missing unimodal RT distribution should equally predict the trimodal RT distribution. Furthermore, the expected RSE can in fact be computed for any combination of uni- and bimodal conditions, which results in a total of seven parameter-free predictions. Remarkably, the empirical effects follow these predictions overall very well. Hence, the associative property holds. Race

models are consequently a strong and consistent candidate framework to explain the RSE and provide a powerful tool to investigate and understand perceptual decisions with multisensory signals.

Estimating non-decision time in visuo-saccadic response time

CT

Bompas, Aline; Sumner, Petroc; Hedge, Craig

CUBRIC - School of Psychology, Cardiff University, United Kingdom

The concept of non-decision time is essential to developing correct understanding and mathematical formulation of decision. Non-decision time represents the portion of a reaction time not devoted to the choice, and corresponds to the sum of sensory conduction delay and motor execution time. More accurate modelling assumptions regarding non-decision time are essential for obtaining reliable estimates of decision parameters.In recent work, we have shown how saccades' sensitivity to visual transients can be used to precisely estimate non-decision time (Bompas et al. Psychological review 2020). This work relies on protocols where visual signals are presented after the onset of the saccade target (saccadic inhibition or stop-task). Using the biologically inspired model DINASAUR, we showed how the timing of interference (or dips) caused by visual transient within the reaction time distribution leads to precise estimates of non-decision time.However, these protocols are not commonly run in the field and often involve a large number of trials. Here we ask to what extent similar conclusions can be reached from simple reaction time data and quantify the impact of lower trial numbers. We first introduce data in which the same stimuli were used either as interfering signals (creating dips) or as saccade targets (producing simple RT distributions) in different blocks. We compare non-decision time estimates from 1) dip timing, 2) shortest RT and 3) drift diffusion model fits. Subsampling from several previous interference protocols with large numbers of trials, we then estimate the robustness of this methods across decreasing sample sizes.

Attention as a source of overall value effects in diffusion models

CT

Shevlin, Blair; Ratcliff, Roger; Krajbich, Ian

The Ohio State University

Research has demonstrated that value-based decisions depend not only on the relative difference between options, but also on their overall value. In particular, response times tend to decrease as the overall value of the alternatives increase. Standard sequential sampling models such as the diffusion model can account for this fact by assuming that decision thresholds or noise vary with overall value. Alternatively, attention-based models that incorporate eye-tracking data produce this overall value effect as a direct consequence of the multiplicative relationship between attention and value. Using a non-attentional diffusion model fit to data simulated with an attention-based model, we find that parameters related to decision thresholds or noise vary as a function of overall value, even though these were not features of the data-generating process. We find additional evidence

for misidentified parameters in a similar analysis using two empirical data sets. In both data sets, models that incorporated attention-based evidence accumulation provided superiors fits to the empirical data and led to different conclusions about value-based boundaries. Our results indicate that neglecting attentional effects can lead to mistaken conclusions about which decision parameters (e.g., noise or thresholds) are sensitive to overall value.

Reaction Time Models

A Circular Diffusion Model of Continuous-Outcome Source Memory Retrieval

CT

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Source memory is memory for the context in which items were previously encountered. Harlow and Donaldson (2013) found evidence of a retrieval threshold underlying source accuracy in a continuous report task. However, this finding did not account for the influence of decision-making in generating responses in memory retrieval. Additional research has also suggested that participants had no source memory for items which were not recognised, which was also not accounted for (Hautus et al., 2008; Malejka & Broder, 2015). In working towards a comprehensive account of decision-making in source memory retrieval, this study used the Smith (2016) circular diffusion model to introduce diffusion analogues of the threshold and continuous models of source memory retrieval in a replication of the Harlow and Donaldson (2013) task. Participant performance was conditioned on item recognition in order to detangle recognition from a potential source retrieval threshold. Model selection done using the BIC found support for a circular diffusion model where memory discretely fails, as both RT and response accuracy data suggested that there were two components in performance.

The timed racing diffusion model of decision making

CT

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1: University of Newcastle; 2: University of Tasmania

Many theories of decision making assume accumulation-to-threshold mechanisms. These thresholds almost always represent a criterion quantity on the 'evidence' or 'information' required to support a decision. We present a quantitative model that involves an additional accumulation-to-threshold mechanism where decisions can be triggered when a sufficient amount of time has been committed to the decision process. We show that a decision architecture composed of a competitive race with evidence-based and time-based thresholds provides a cohesive account of decision-making phenomena, including the speed-accuracy trade-off. We show

that it can also explain phenomena outside the domain of conventional evidence accumulation models, including simultaneously accounting for performance in decision and timing tasks. As a byproduct, the evidence-based vs time-based decision architecture eliminates the need for decision-to-decision variability parameters that are key elements of many accumulation-based theories of decision making.

An extension of the LBA-IRT model to multidimensional multiple-alternative forced-choice personality measurement with response times

CT

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The objective of the present study is to develop a model applicable to multiple-alternative forced-choice (MAFC) personality measurement data that include both item responses and response times. To this end, we started from the linear ballistic accumulator-item response theory (LBA-IRT) model, which is one of the cognitive models of two-alternative forced-choice item responses and response times. However, this model cannot be applied to MAFC data because of its formulation of the drift rate parameter. To address this problem, the present study proposes a novel formulation allowing the model to be applied to MAFC personality measurement. The proposed formulation of the drift rate is based on Thurstone's random utility model and Luce's choice axiom. We applied the proposed model to two real data sets and showed that the proposed model can estimate respondents' personality traits more reasonably than existing models for MAFC data that include the Thurstonian diffusion IRT model.

fMTP: A Unifying Computational Framework of Temporal Preparation across Time Scales

CT

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In warned reaction time (RT) tasks, a warning stimulus (S1) initiates a process of temporal preparation which promotes a speeded response to the target stimulus (S2). Variations of the S1-S2 interval (foreperiod) have been shown to affect the RT to S2 across a range of time scales: within trials, between consecutive trials, across trials within an experimental block, and across blocks. RT distribution analyses suggest that these effects share a common mechanism, and yet theories on preparation have thus far failed to offer an integrative account of these phenomena. We present a computational framework (fMTP) that formalizes the principles of a previously proposed theory of temporal preparation: Multiple Trace Theory of Temporal Preparation. With fMTP we combine models and theories on time perception, motor planning, and associative learning into a single, computational theory. fMTP assumes that for each trial a unique trace is formed by means of associative

Hebbian learning between a layer of time cells and a motor layer with an inhibition and activation node. On each new trial, traces from the past collectively determine the temporal preparatory state. We compared fMTP to existing theories which were not yet formalized until now. This model exploration demonstrated that fMTP best described existing data sets. In addition, in an experiment that was set out to validate fMTP, we show the data to align with our model predictions. In sum, we find that fMTP's single implicit learning mechanism suffices to explain a range of phenomena that previously have been considered to be the result of distinct processes.

Degenerate Optimal Boundaries for Multiple-Alternative Decision Making

CT

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Integration-to-threshold models of two-choice perceptual decision making have guided our understanding of the behaviour and neural processing of humans and animals for decades. Although such models seem to extend naturally to multiple-choice decision making, consensus on a normative framework has yet to emerge, and hence the implications of threshold characteristics for multiple choices have only been partially explored. Here we consider sequential Bayesian inference as the basis for a normative framework together with a conceptualisation of decision making as a particle diffusing in n-dimensions. This framework implies highly choice-interdependent decision thresholds, where boundaries are a function of all choice-beliefs. We show that in general the optimal decision boundaries comprise a degenerate set of complex structures and speed-accuracy trade-offs, contrary to current 2-choice results. Such boundaries support both stationary and collapsing thresholds as optimal strategies for decision-making, both of which result from stationary complex boundary representations. This casts new light on the interpretation of urgency signals reported in neural recordings of decision making tasks, implying that they may originate from a more complex decision rule, and that the signal as a distinct phenomenon may be misleading as to the true mechanism. Our findings point towards a much-needed normative theory of multiple-choice decision making, provide a characterisation of optimal decision thresholds under this framework, and inform the debate between stationary and dynamic decision boundaries for optimal decision making.

The Trail Making Test: a simple model based on an eye-tracking study

CT

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In this paper we address the question of whether is it possible to model as a dynamical problem the behavior of subjects performing a neuropsychological test. We address the task employing the Trail Making Test in its part A. To be able to model

the subjects behavior we first implement a digital version of the test which allow us to register the eye movements of the subjects during the performance. Then we analyze the eye tracking data and explore the behavior to be able to propose an equation representing the dynamics. With the equation at hand, an analysis of the parameters is performed in such a way different magnitudes could be related to neuropsychological constructs like processing speed, visual search speed and mental flexibility.

Applied MathPsych

An application of a hierarchical diffusion model on ambulatory data from Huntington's patients

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CT

1: Indiana University Bloomington; 2: Monash University

Huntington's disease is a debilitating neurodegenerative illness involving motor and cognitive impairments throughout its progression, eventually leading to death. Diagnosis is based on motor symptoms; however, the cognitive symptoms are more debilitating. Assessing the disease's consequences on cognition can hint at what processes should be targeted for cognitive-behavioral treatment. We present an application of a hierarchical diffusion model (Ratcliff et al., 2016; Vandekerckhove et al., 2010) to an ambulatory assessment with manifest (HD) and premanifest (PM) Huntington's patients and compare their performance, as assessed by the model, to performance from controls on a numerosity task (McLaren et al., 2020). We found a gradation of impairment across the groups in the mean drift rate, such that: (1) HD always had a lower drift rate than controls; (2) HD had lower drift rates than PM in the easy condition, but they had essentially equivalent rates in the difficult condition; (3) PM had lower drift rates than controls in the difficult condition, but they had essentially equivalent rates in the easy condition. These results held even after regressing on age for all groups, and were not observed when analyzing average response times or correct/incorrect response percentages. Our Bayesian approach also allowed us to assess which parameters were most reliably estimated with ambulatory data through the Gelman-Rubin statistic. Overall, we found that the hierarchical diffusion model provided novel insights into the progression of Huntington's disease, with our Bayesian model providing a powerful method of assessment and group separation even with in-home, ambulatory data on mobile phones.

Acute Alcohol Effects on Risky Sexual Decision Making

CT

Hatz, Laura; McCarthy, Denis; Davis-Stober, Clintin

University of Missouri

In previous studies, we tested properties of sexual decision making using a novel sexual gambles task in which participants made repeated choices between hypothetical sexual partners based on physical attractiveness and risk of contracting a sexually transmitted infection (STI). We found that the vast majority of participants ($\approx 98\%$) used a rational, compensatory strategy when choosing between partners and that between-subject variability in choice behavior was associated with sexual attitudes and behaviors (Hatz et al., in press). In the present study, we tested whether this pattern of results would hold under acute alcohol intoxication, a manipulation known to impact cognitive processing abilities. Young adult moderate drinkers ($N = 44$) were recruited from a large Midwestern university and surrounding community to participate in a double-blind, within-subjects laboratory alcohol administration study consisting of counterbalanced alcohol (target peak $BrAC = 0.10g\%$) and placebo sessions. Participants completed the sexual gambles task at matched points ($BrAC \approx .080\%$) on the ascending and descending limbs of intoxication in the alcohol session and at approximately matched points in the placebo session. We used Bayesian model selection to test whether participants used a compensatory (i.e., a numerical utility representation) or non-compensatory decision making strategy on the task. We then used a p-median clustering algorithm (Brown et al., 2016) to identify between-subject variability in choice behavior. In a replication of our previous findings, nearly all participants used a compensatory strategy when making sexual decisions, regardless of beverage condition or limb of intoxication. Results and implications will be discussed.

Identifying computational markers of future nicotine intake using adaptive design optimization in a smartphone app

CT

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Nicotine addiction is a major health problem worldwide, and it is imperative that we develop reliable and inexpensive tools for predicting its treatment outcomes. Recent studies suggest that computational modeling and associated tools may provide us with neurocognitive markers of addictive disorders. Importantly, adaptive design optimization (ADO), which guides stimulus selection in an optimal way, may lead to rapid, precise, and reliable markers of addictive disorders. Large-scale mobile or wearable data may also reveal digital phenotypes for daily-life, but it remains untested if ADO may contribute to developing optimized digital phenotypes for addictive behaviors. Here, we conducted a longitudinal study with 43 individuals participating in a smoking cessation clinic for up to 6 weeks to investigate if ADO-

based markers from a smartphone app may predict their future nicotine intake. Two ADO-based cognitive tasks provided individuals' model parameters regarding their decision-making on a daily basis. Participants also answered surveys regarding their smoking-related behaviors and psychological states every day. The results suggest that ADO-based digital phenotypes (in a smartphone app) show great test-retest reliability at a similar performance level to laboratory-based ADO-based markers. Time-lagged regression analyses using daily ADO-based digital phenotypes and survey responses revealed several significant features that predicted the amount of smoking on the next day while model parameters such as risk sensitivity and ambiguity sensitivity accounted for subjects' mean-level of nicotine intake. These findings suggest that ADO may contribute to the development of reliable digital phenotypes in daily life.

Who's more Bayesian? Belief updating and no conservatism bias in Schizophrenia

CT

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We update our beliefs based on evidence but often slower than Bayesian theory demands. Beliefs in stability may lead to these conservatism bias. Notably, patients with delusions do not show the conservatism bias and can be more Bayesian in probabilistic reasoning tasks. Still, their reasoning has been explained with reduced general cognitive abilities, i.e., a lower working memory capacity, overweighting of recent information, or lower thresholds for switching from one belief to another. We modeled the graded estimate version of the beads task, i.e. a task where one sees two jars containing opposite ratios of colored beads. One then estimates the probability that a shown bead comes from jar A. We model the deviations from an ideal Bayesian observer on three independent data sets, totalling $n = 176$ healthy controls and $n = 128$ patients with schizophrenia. The parameters describe (a) the number of beads considered (memory), (b) systematic deviation and (c) unsystematic deviations (volatility) from probability estimates. We find that on average patients consider fewer beads, and show more volatile responding. However, patients have on average probability estimates that are closer to the true probabilities and hence show less of a conservatism bias. Our mathematical model captures well the cognitive mechanisms proposed to contribute to performance differences, known as jumping to conclusion bias, in the beads task. It also shows that taking fewer data into account may reduce a cognitive bias.

Bayesian hierarchical estimation of visual change detection using Gaussian Markov Random Field priors

CT

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In the visual change detection paradigm, observers are shown two stimuli in succession, labeled x and y, and are asked to report whether they are the same or different. The goal in such studies is to determine the probability that an observer will detect a difference as a function of the stimuli, represented by $f(x, y)$. However, when the number of possible stimuli is large, it is infeasible to sample all (x, y) combinations. Bayesian hierarchical models offer a solution to this problem by introducing statistical dependencies between variables (e.g., different observers or different stimuli). In this work, we utilize a Gaussian Markov Random Field (GMRF) prior to estimate visual sensitivity. GMRFs are a technique from spatial statistics that introduces dependencies between variables based on their proximity. As applied to the change detection paradigm, such a prior assumes that $f(x, y)$ should be similar to $f(x + \delta, y)$. Our approach allows for the estimation of the complete function $f(x, y)$ even when the stimulus space is sparsely sampled. Posterior inference for the model is performed using MCMC, implemented via the Stan software package. We apply our approach to a change detection experiment in which stimuli were visually complex animations of geologic faults varying in their structural features. Research participants were novices to the domain of geology, who first underwent one of two training sessions that introduced knowledge of different geologic fault categories. Our analysis reveals a significant effect of category knowledge on visual working memory performance.

How does risk perception of COVID-19 influence emotion and mental health during the pandemic: A specification curve analysis

CT

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COVID-19, a public health emergency of international concern as declared by WHO, is rapidly sweeping the world. Emerging evidence on risk perception and public responses during the pandemic (e.g. SARS, H1N1) implied that risk perception could be highly related to emotion or even mental health (Qian, et.al, 2003; Raude & Setbon, 2009; Bults, et.al, 2011). This study was based on the PsyCorona Survey, an international project on COVID-19 covering over 56,000 participants from 96 countries. Specification curve analysis (SCA) was used to examine the relationship of risk perception of COVID-19 with emotion and self-rated mental health, which considers all reasonable model settings to avoid subjective bias on modelling choices. Firstly, 162 multilevel linear regression models were established for risk perception and

emotion, all of which indicated that high risk perception of COVID-19 significantly increases the level of negative emotions (median $\beta = 0.24$, $P < 0.001$) and reduces the level of positive emotions (median $\beta = -0.18$, $P < 0.001$). Moreover, higher risk perception was also associated with worse mental health ($\beta = -0.19$, $P < 0.001$). We further used SCA to explore whether the relationship between risk perception and mental health is mediated by emotion. Among the 54 regressions of mental health on risk perception and emotion, 36 models showed a strong mediation effect, with no significant direct effect of risk perception on mental health after controlling for emotion. We concluded that the risk perception of COVID-19 could influence emotion and ultimately have impact on mental health.

Axiomatics and Formal Analysis

On the functional forms in a psychophysical law of similarity under a subtractive representation

CT

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Writing ξ_s(x) for the stimulus intensity judged greater (louder, heavier, brighter) than stimulus intensity x with criterion s, Iverson (2006) proposed a law of similarity $\xi_s(\lambda x) = \gamma(\lambda, s)\xi_{\eta(\lambda,s)}(x)$ to model the dependence of $\xi_s(x)$ on x. This model, which has $\eta(\lambda, s)$ and $\gamma(\lambda, s)$ as parameters, is quite general and may be applied in a number of situations in psychophysics. Iverson (2006) analyzed this model assuming the representation $s = u(\xi_s(x)) - u(x)$ and derived the possible functional forms for the scale u. In the present work, we extend the analysis to the more general $s = u(\xi_s(x)) - w(x)$ and derive the forms for the scales u and w. We avoid the assumption of differentiability and replace it with an assumption either of non-constancy or of dependence on only one input variable. We find that for some solutions, w has the same form as u, reflective of the context for which $u = w$, while for other solutions, w takes a different form than u. Comparisons are made to Iverson (2006) and to other work.

Information Geometry and Statistical Mirror Symmetry

CT

Zhang, Jun; Khan, Gabriel

University of Michigan

Information geometry investigates parametric families of statistical model by representing probability density functions over a given sample space as points of a differentiable manifold M. Treating parameters as a local coordinate chart, M is endowed with a Riemannian metric g given by the Fisher-information (the well-known Fisher-Rao metric). Such characterization has found many applications in machine learning, statistical inference, optimization, neural networks, information theory, etc. The classical theory of information geometry also prescribes a family of

dualistic, torsion-free alpha-connections constructed from Amari-Chensov tensor as deformation from the Levi-Civita connection associated with g. Here we prescribe an alternative geometric framework of the manifold M by treating the parameter as an affine parameter of a flat connection and then prescribing its dual connection (with respect to g) ∇ as one that is curvature-free but carries torsion. We show that its tangent manifold TM has the structure of a Hermitian manifold constructed from the flat connection and an almost Kahler structure constructed from ∇. Therefore, we establish a "mirror correspondence," that is, a correspondence between a complex (Hermitian) structure and a symplectic (almost Kahler) structure discovered in String Theory, for parametric statistical models! Examples of such mirrors will be shown for some examples, such as the family of univariate normal distributions.

A New Axiomatization of Luce's Model of Choice and Ranking

CT

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1: University of California, Irvine; 2: Independent Scholar; 3: Chiang Mai University, Thailand

Suppose that an agent is asked to rank the elements of a finite set U, starting with the most preferred and ending with the least. These rank orders may vary stochastically from occasion to occasion. Let P_U denote the agent's probability distribution of rankings of U. Duncan Luce's well-known Choice Axiom, together with his Ranking Postulate, imply that the P_U distribution will be a member of the Plackett-Luce family. We derive Luce's Choice Axiom, rather than assuming it. Suppose that T and S are any disjoint sets whose union is U. Let T_s and S_s denote any specifications of of the preference order over the elements of T and S, respectively. Let S_f denote the event that every element of S is preferred to every element of T. Our Axiom of Independence from the Past (AIFP) states that the events T_s and $S_s \cap S_f$ are independent under P_U. This axiom implies that P_U is a Plackett-Luce distribution. Our Rational Choice Axiom states that, when the agent chooses an element from a subset T of U, the agent consults its preference ranking over U and selects the element of T that is highest ranked. Together, this axiom and the AIFP imply Luce's Choice Axiom. In addition, we formulate a ranking mechanism, based on Goodman and Nguyen's Product Space Conditional Event Algebra, whose behavior conforms to the AIFP.

Contextuality as an extension of selective influences

CT

Dzhafarov, Ehtibar N.

Purdue University

In 1969 Sternberg introduced the notion of experimental factors selectively influencing random variables representing mental processes. In the early 2000s this notion was extended to stochastically non-independent variables. Traditionally one uses it by postulating a pattern of selective influences, and reconstructing mental architectures from the overall effect of the experimental factors on some overall measure of performance, e.g., response time. However, whenever one relates experimental factors to random variables that are directly observable, one finds

that the pattern of influences is not selective: it invariably violates marginal selectivity, the crudest necessary condition of selectiveness. This prevents one from applying selective influences to such seemingly closely related issues as separability/integrality of perceptual tasks. In fact, the notion of selective influences seems to have no applications except to hypothetical variables one cannot observe – an intellectually unsatisfactory situation. The modern contextuality analysis, in which theory of selective influences converges with foundations of quantum mechanics, provides a way out, and offers a powerful mathematical language for addressing in a new way a variety of traditional issues, including the separability/integrality one. The notion of selective influences is a special case of a noncontextual system with marginal selectivity. However, in the theory dubbed Contextuality-by-Default, a system can be noncontextual or contextual irrespective of whether marginal selectivity is satisfied, and the degree of both contextuality and noncontextuality can be measured together with the degree of marginal selectivity. The theory also has prominent applications outside psychology, e.g., in quantum physics and computer science.

Detecting Contextuality in Systems with Categorical Variables

CT

Cervantes Botero, Víctor Hernando

Purdue University

The Contextuality-by-Default theory describes contextual effects on random variables: how the identity of random variables changes from one context to another. Direct influences and true contextuality constitute different types of effects of contexts upon sets of random variables. Changes in the distributions of random variables across contexts define direct influences. True contextuality is defined by the impossibility of sewing all the variables of a system of random variables into a particular overall joint distribution where variables that correspond to the same property in different contexts are equal to each other as often as possible.For systems of binary random variables, the theory shows that, in cyclic systems, the two effects are in opposition. For the extension of the theory to systems with categorical random variables, I will present the nominal dominance theorem, which states a necessary condition for noncontextuality of systems where all dichotomizations of categorical variables are considered. This condition shows a case where direct effects may entail true contextuality. I will also illustrate the application of this theorem to the results of a psychophysical double-identification experiment.

Applications of Information Theory to Perceptual Independence and Separability

CT

Akrenius, Mikaela

Indiana University

Ever since the inception of the notion of perceptual independence, questions related to the processing of perceptually independent or separable dimensions have been intertwined with assumptions made about perceptual distributions, infor-

mational overlap, and channel capacity. Even though several successful empirical protocols and theoretical frameworks have been proposed for recognizing violations of perceptual independence or separability, few of them dissociate between different kinds of violations or on the potentially separate cognitive processes underlying these violations. Furthermore, despite of strong historical connections to Garner et al.'s work in the intersection of information theory and perceptual independence, few approaches take advantage of these connections. We revive Garner and Morton's (1969) classic uncertainty analysis, combine it with contemporary information-theory-based tools and metrics, and reanalyze a set of simulated and empirically observed confusion matrices from modern studies. Our results shed light on the locus of interaction of perceptually integral dimensions, help build bridges between different notions of perceptual separability, and identify areas of research in which uncertainty analysis could complement existing methods for inferring perceptual processes.

ICCM Session I

Amortized Bayesian Inference for Models of Cognition

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As models of cognition grow in complexity and number of parameters, Bayesian inference with standard methods can become intractable, especially when the data-generating model is of unknown analytic form. Recent advances in simulation-based inference using specialized neural network architectures circumvent many previous problems of approximate Bayesian computation. Moreover, due to the properties of these special neural network estimators, the effort of training the networks via simulations amortizes over subsequent evaluations which can re-use the same network for multiple data sets and across multiple researchers. However, these methods have been largely underutilized in cognitive science and psychology so far, even though they are well suited for tackling a wide variety of modeling problems. With this work, we provide a general introduction to amortized Bayesian parameter estimation and model comparison and demonstrate the applicability of the proposed methods on a well-known class of intractable response-time models.

A Distributed Spiking Neuron Model of Attention in the Stroop Task

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We present a spiking neuron-based model of the Stroop task where the attention mechanism is entirely implemented with distributed representations. This is done by using the Neural Engineering Framework and the associated Semantic Pointer Architecture to implement a selective attention mechanism. The resulting system exhibits the Stroop effect, as well as the associated Facilitation and Interference effects. In contrast with previous models, these effects are not generated via a localist competition mechanism. Rather, these effects are a result of controlled unbinding of information from a combined distributed representation.

Neurally-informed modelling of static and dynamic decision biases

Martinez-Rodriguez, L. Alexandra (1); Corbett, Elaine A. (2); O'Connell, Redmond G. (2); Kelly, Simon P. (1)

1: University College Dublin, Ireland; 2: Trinity College Dublin, Ireland

CS

Different accounts have been developed to explain the mechanisms underlying value biases during perceptual decision-making, within the model framework of bounded accumulation. The starting point bias account suggests a shift in the starting point of evidence accumulation, in the direction of the more valuable alternative. The drift rate bias account suggests that the mean rate of accumulation is steepened for the more valuable alternative. While most studies have supported a starting point bias (SPB) approach, recent work (Afacan-Seref et al., 2018) suggests that drift rate biases (DRB) may also be applied in certain circumstances. Here, we used human EEG signatures of competitive motor preparation to construct a cognitive decision model that can explain the biasing mechanisms through which participants perform a value-biased orientation discrimination task under a strict deadline. Motor preparation dynamics showed signs of a value bias that emerged prior to evidence onset and increased steadily with time. Accordingly, we constructed a model that included an anticipatory dynamic urgency signal towards the High Value alternative. This model provided a better fit to behaviour than models with either a starting point or a drift rate bias but no anticipatory dynamics. These results point to a role for value-modulated, anticipatory motor preparation in fast-paced decision-making tasks, and suggest a unitary mechanism that can generate both static (starting point) and dynamic (drift rate) biases at the same time.

Cognitive Saliency of Features in Cyber-attacker Decision Making

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CS

While much is known about how humans make decisions based on the recency, frequency, and similarity of past experiences, much less is known about how humans weigh the contextual features and the impact it has on decisions. The present study uses a novel method of introspecting into a cognitive model of human decision making in an abstract cybersecurity game to gain insight about the cognitive salience of the features. The results show that cognitive salience can provide valuable evidence about how and why individuals make their decisions. The implications of these results are discussed with regard to theory and application.

Connecting Biological Detail with Neural Computation: Application to the Cerebellar Granule-Golgi Microcircuit

CS

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1: Centre for Theoretical Neuroscience, University of Waterloo, Canada; 2: National Research Council of Canada, University of Waterloo Collaboration Centre, Canada

Neurophysiology and neuroanatomy limit the set of possible computations that can be performed in a brain circuit. Although detailed data on individual brain microcircuits is available in the literature, cognitive modellers seldom take these constraints into account. One reason for this is the intrinsic complexity of accounting for mechanisms when describing function. In this paper, we present multiple extensions to the Neural Engineering Framework that simplify the integration of low-level constraints such as Dale's principle and spatially constrained connectivity into high-level, functional models. We apply these techniques to a recent model of temporal representation in the Granule-Golgi microcircuit in the cerebellum, extending it towards higher degrees of biological plausibility. We perform a series of experiments to analyze the impact of these changes on a functional level. The results demonstrate that our chosen functional description can indeed be mapped onto the target microcircuit under biological constraints. Further, we gain insights into why these parameters are as observed by examining the effects of parameter changes. While the circuit discussed here only describes a small section of the brain, we hope that this work inspires similar attempts of bridging low-level biological detail and high-level function. To encourage the adoption of our methods, we published the software developed for building our model as an open-source library.

Interactive Grounding and Inference in Instruction Following

CS

Salvucci, Dario D.

Drexel University

Learning by instruction is one of the most common forms of learning, and a number of research efforts have modeled the cognitive process of instruction following, with many successes. However, most computational models remain brittle with respect to the given instructions and lack the ability to adapt dynamically to variants of the instructions. This paper aims to illustrate modeling constructs designed to make instruction following more robust, including (1) more flexible grounding of language to execution, (2) processing of instructions that allows for inference of implicit instruction knowledge, and (3) dynamic, interactive clarification of instructions during both the learning and execution stages. Examples in the context of a paired-associates task and a visual-search task are discussed.

Integrated Model of Fatigue and C-17 Approach and Landing Operations

CS

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1: Tier1 Performance Solutions; 2: Air Force Research Laboratory; 3: L3Harris

Fatigue is a common occurrence in several occupational fields, often resulting in operator performance and health issues. Biomathematical models of fatigue have become useful tools in several fatigue risk management programs. However, these tools still have limitations in terms of identifying specific performance outcomes affected by fatigue, as well as individualizing fatigue estimates to individual operators. The integration of computational cognitive models and biomathematical models can help solve these issues in a complex operational context. The current effort aims to develop an integrated model of fatigue in the context of C-17 approach and landing operations. Specifically, we integrate a biomathematical fatigue model with a task network model to estimate performance degradation due to fatigue. The following paper outlines the development of the task network model and integration with the biomathematical fatigue model.

The Need for Speed: Effects of Human Derived Time Constraints on Performance and Strategy in Machine Models of Tetris

CS

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1: University of Washington, Department of Psychology; 2: Rensselear Polytechnic Institute, Cognitive Science Department

One of the hallmarks of expert performance in complex, dynamic tasks is the ability to select and perform the appropriate action within a constantly shifting environment, often under tight time constraints. In an example task, the video game Tetris, expert players select placement positions for the active zoid and navigate them into place in increasingly short time spans. Machine models of the same task are capable of producing human-like performance patterns, but either ignore or only roughly approximate the time constraints that seem to be an integral part of human behavior. Using a set of scaled time parameters derived from a large set of human subjects, we trained and tested an existing machine Tetris model and observed the resultant changes in performance and behavior.

Cognitive Mechanisms for Calibrating Trust and Reliance on Automation

CS

Blaha, Leslie (1); Lebiere, Christian (2); Fallon, Corey (3)

1: Air Force Research Laboratory; 2: Carnegie Mellon University; 3: Pacific Northwest National Laboratory

Trust calibration for a human-autonomy team is the process by which a human adjusts their understanding of the automation's capabilities; trust calibration is needed to engender appropriate reliance on automation. Herein, we develop an Instance-based Learning Theory ACT-R model of decisions to obtain and rely on an automated assistant for visual search in a UAV interface. We demonstrate that model matches well the human predictive power statistics measuring reliance calibration; we obtain from the model an internal estimate of automation reliability that mirrors human subjective ratings. Our model is a promising beginning toward a computational process model for trust and reliance for human-machine teaming.

Cognitive Twin: A Cognitive Approach to Personalized Assistants

CS

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1: Carnegie Mellon University, United States of America; 2: Bosch Research and Technology Center

This paper presents an analysis of a cognitive twin, implemented in a cognitive architecture. The cognitive twin is intended to be a personal assistant that learns to make decisions from your past behavior. In this proof-of-concept case, we have the cognitive twin select attendees to a party, based upon what it has learned (through

ratings) about an agent's social network. We evaluate two versions of a model with respect to rate of change in the social network, the noise in the rating data, and the sparsity of the data.

ICCM Session III

Time-related Effects of Speed on Motor Skill Acquisition

CS

Gianferrara, Pierre Giovanni; Betts, Shawn; Anderson, John Robert

Carnegie Mellon University, United States of America

Anderson et al. (2019) present an ACT-R model of how humans learn to play rapid-action video games. To further test this model, we utilized new measures of action timing and sequencing to predict skill acquisition in a controlled motor task named Auto Orbit. Our first goal was to use these measures to capture time-related effects of speed on motor skill acquisition, operationalized as a performance score. Our second goal was to compare human and model motor skill learning. Our results suggest that humans rely on different motor timing systems in the sub- and supra-second time scales. While our model successfully learned to play Auto Orbit, some discrepancies in terms of motor learning were noted as well. Future research is needed to improve the current model parametrization and enable ACT-R's motor module to engage in rhythmic behavior at fast speeds.

Modeling intrinsic motivation in ACT-R: Focusing on the relation between pattern matching and intellectual curiosity

CS

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To be keen learners, humans need not only external rewards but also internal rewards. To date, there have been many studies on environment learning using intrinsic motivation for artificial agents. In this study, we aim to build a method to express curiosity in new environments via the Adaptive Control of Thought-Rational (ACT-R) cognitive architecture. This model focuses on the "production compilation" and "utility" modules, generic functions of ACT-R, and it regards pattern matching in the environment as a source of intellectual curiosity. We simulated a path-planning task in a maze environment using the proposed model. The model with intellectual curiosity showed that understanding of the environment was improved by the task of searching the environment. Furthermore, we implemented the model using a standard reinforcement learning agent and compared it with the ACT-R model.

An Imperative Alternative to Productions for ACT-R

CS

Harrison, Anthony

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As cognitive modeling has matured, so too have its tools. High-level languages are such tools and present a rich opportunity for the acceleration and simplification of model development. Reviewing some of a the major contributors to this area, a new language (Jass) is introduced for building ACT-R models. Jass simplifies and accelerates model development by providing an imperative language that is compiled to production rules. A complex model implemented using this language is detailed.

Detecting Learning Phases to Improve Performance Prediction

CS

Collins, Michael (1); Tenison, Caitlin (2); Gluck, Kevin (1); Anderson, John (3)

1: Cognitive Models and Agents Branch, United States of America; 2: Educational Testing Service; 3: Carnegie Mellon University

Models of learning and retention make predictions of human performance based on the interaction of cognitive mechanisms with temporal features such as the number of repetitions, time since last presentation, and item spacing. These features have been shown to consistently influence performance across a variety of domains. Typically omitted from these accounts are the changes in cognitive process and key mechanisms used by people while acquiring a skill. Here we integrate a model of skill acquisition (Tenison & Anderson, 2016) with the Predictive Performance Equation (PPE; Walsh, Gluck, Gunzelmann, Jastrzembski, & Krusmark, 2019) using Bayesian change detection (Lee, 2019). Our results show this allows for both better representation of an individual's performance during training and improved out-of-sample prediction.

Reinforcement Learning for Production-based Cognitive Models

CS

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1: UC Santa Cruz, United States of America; 2: Utrecht University, The Netherlands

We introduce a framework in which we can start exploring in a computationally explicit way how complex, mechanistically specified, and production-based cognitive models of linguistic skills, e.g., ACT-R based parsers, can be acquired. Linguistic cognitive model learnability is a largely understudied issue, primarily because computationally explicit cognitive models are only starting to be more widely used in psycholinguistics. Cognitive models for linguistic skills pose this learnability problem much more starkly than models for other 'high-level' cognitive processes, since cognitive models that use theoretically-grounded linguistic representations and processes call for richly structured representations and complex rules that require a significant amount of hand-coding.

The Power of Nonmonotonic Logics to Predict the Individual Reasoner

CS

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Human reasoning deviates from classical logic. Psychological findings demonstrate that human reasoning is nonmonotonic, i.e., new information can lead to the retraction of previous inferences, it is defeasible reasoning. It is relevant whenever no contrary information is known (defeasible reasoning), when a most likely explanation is sought (abductive reasoning), when we need to revise our initial beliefs (belief revision), or to model human 'commonsense reasoning' a topic highly relevant in AI research. While analysis of population data has identified nonmonotonic features, it is an open question, if systems that capture nonmonotonic reasoning better captures individual human reasoning. In this article, we take three prominent nonmonontonic approaches, the Weak Completion Semantics, Reiters Default Logic, and OCF, a ranking on possible worlds, implement variants of them and evaluate them within the CCOBRA-framework for their predictive capability in the Suppression Task. We demonstrate that both systems achieve a high performance being able to predict on average 82% of the inference drawn by an individual reasoner. Furthermore, we can demonstrate that OCF and an improved version of Reiter make identical predictions and that abduction is relevant on the level of an individual reasoner. We discuss implications of logical systems for human reasoning.

Effects of Decision Complexity in Goal-seeking Gridworlds: A Comparison of Instance-Based Learning and Reinforcement Learning Agents

CS

Nguyen, Thuy Ngoc; Gonzalez, Cleotilde

Dynamic Decision Making Laboratory, Carnegie Mellon University, USA

Decisions under uncertainty are often made by weighing the expected costs and benefits of the available options. The trade-offs of costs and benefits make some decisions easy and some difficult, particularly given uncertainty of these costs and rewards. In this research, we evaluate how a cognitive model based on Instance-Based Learning Theory (IBLT) and two well-known reinforcement learning (RL) algorithms learn to make better choices in a goal-seeking gridworld task under uncertainty and on increasing degrees of decision complexity. We also use a random agent as a base level comparison. Our results suggest that IBL and RL models are comparable in their accuracy levels on simple settings, but the RL models are more efficient than the IBL model. However, as decision complexity increases, the IBL model is not only more accurate but also more efficient than the RL models. Our results suggest that the IBL model is able to pursue highly rewarding targets even when the costs increase; while the RL models seem to get "distracted" by lower costs, reaching lower reward targets.

Information Theory Meets Expected Utility: The Entropic Roots of Probability Weighting Functions

CS

Akrenius, Mikaela

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This paper proposes that the shape and parameter fits of existing probability weighting functions can be explained with sensitivity to uncertainty (as measured by information entropy) and the utility carried by reductions in uncertainty. Building on applications of information theoretic principles to models of perceptual and inferential processes, we suggest that probabilities are evaluated relative to a plausible expectation (the uniform distribution) and that the perceived distance between a probability and uniformity is influenced by the shape (relative entropy) of the distribution that the probability is embedded in. These intuitions are formalized in a novel probability weighting function, VWD(p), which is simpler and has less parameters than existing probability weighting functions. The proposed probability weighting function captures characteristic features of existing probability weighting functions, introduces novel predictions, and provides a parsimonious account of findings in probability and frequency estimation related tasks.

One Size Doesn't Fit All: Idiographic Computational Models Reveal Individual Differences in Learning and Meta-Learning Strategies

CS

Haile, Theodros; Prat, Chantel; Stocco, Andrea

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Learning occurs through the interaction of working memory (WM), declarative memory (LTM) and reinforcement learning (RL). There are vast individual differences in learning mechanism deployment and it is often difficult to assess the relative contributions of these systems during learning through behavioral measures. Collins (2018), forwarded a working memory - reinforcement learning combined model that addresses this issue but seems to lack a robust declarative memory component. In this project we built four (two single-mechanism RL and LTM, and two integrated RL-LTM) idiographic learning models based on the ACT-R cognitive architecture. We aimed to examine individual differences and fit parameters that could explain preferential use of learning mechanisms using the Collins (2018) stimulus-response association task. We found that multiple models provided best-fits for individual learners with more variability in learning and memory parameters observed even within the best fitting models.

ICCM Session V

Modeling cross-language structural priming in sentence production

CS

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A central question in the psycholinguistic study of multilingualism is how syntax is shared across languages. We implement a model to investigate whether error-based implicit learning can provide an account of cross-language structural priming. The model is based on the Dual-path model of sentence-production (Chang, 2002). We implement our model using the Bilingual version of Dual-path (Tsoukala, Frank, & Broersma, 2017). We answer two main questions: (1) Can structural priming of active and passive constructions occur between English and Spanish in a bilingual version of the Dual-path model? (2) Does cross-language priming differ quantitatively from within-language priming in this model? Our results show that cross-language priming does occur in the model. This finding adds to the viability of implicit learning as an account structural priming in general and cross-language structural priming specifically. Furthermore, we find that the within-language priming effect is somewhat stronger than the cross-language effect. In the context of mixed results from

behavioral studies, we interpret the latter finding as an indication that the difference between cross-language and within-language priming is small and difficult to detect statistically.

What Everyday Activities Reveal About Spatial Representation and Planning Depth

CS

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Successfully performing everyday activities such as loading the dishwasher or setting the table relies on the involvement of many cognitive abilities. As such, everyday activities provide a unique window for investigating the involved cognitive abilities as well as their interaction, promising high ecological validity of the obtained findings. Against this background we investigated two cognitive abilities and their combination, which are crucial for virtually all everyday activities. Specifically, we investigated the nature of mental spatial representation and planning depth in rational planning by analyzing table setting behavior across many environments and actors. As recent modeling work indicates that rational planning is influenced by spatial properties of the environment, we investigate how representation of and reasoning about the spatial environment impact sequential action planning. Using a modeling approach, we compare models implementing different plannings depths and differently complex spatial representations. Our findings indicate that people plan opportunistically (one step ahead) and rely on a two-dimensional representation of their environment. These findings lend credit to the idea that humans minimize their cognitive effort (simpler representations, shallow planning) to efficiently perform everyday tasks.

Characterizing Pause Behaviors in a Science Inquiry Task

CS

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In inquiry-based learning tasks students are actively involved in learning knowledge and skills through experimentation. The success of these activities largely depends on student's inquiry practices. While traditional assessment infers student competency from their responses and problem-solving steps, the pauses between these actions provide a valuable source of information. Pauses during inquiry tasks capture a wide range of productive and unproductive activities such as planning, reasoning and mind-wandering. We present efforts to characterize the pauses behaviors during a science inquiry task using hidden Markov modeling. We explore how theory can inform data driven modeling approaches, describe initial evidence of meaningful pause states, and consider the limitations of this approach for supporting inferences about students' science inquiry practices.

Modeling the Effects of Post-Traumatic Stress on Hippocampal Volume

CS

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University of Washington, United States of America

Post-Traumatic Stress Disorder (PTSD) is a psychiatric disorder often characterized by the unwanted re-experiencing of a traumatic event through nightmares, flashbacks, and/or intrusive memories. This paper presents a neurocomputational model using the ACT-R cognitive architecture that simulates intrusive memory retrieval following a potentially traumatic event (PTE) and derives predictions about hippocampus volume observed in PTSD. Memory intrusions were captured in the ACT-R Bayesian framework by weighting the posterior probability with an emotional intensity term I to capture the degree to which an event was perceived as dangerous or traumatic. It is hypothesized that (1) Increasing the intensity I of a PTE will increase the odds of memory intrusions; and (2) Increased intrusions will result in a concurrent decrease in hippocampal size. A series of simulations were run and it was found that I had a significant effect on the probability of experiencing traumatic memory intrusions following a PTE. The model also found that I was a significant predictor of hippocampal volume reduction, where the mean and range of simulated volume loss match results of existing meta-analysis. The authors believe that this is the first model to both describe traumatic memory retrieval and provide a mechanistic account of changes in hippocampal volume, capturing one plausible link between PTSD and hippocampus size.

A grammatically robust cognitive mode of English and Korean sentence processing

CS

Jones, Stephen Mark

University of Groningen

This paper presents a novel approach to the cognitive modelling of human sentence processing in ACT-R. The model assumes a cognitive distinction between cross-linguistic knowledge of the overall possibilities for combining elements of language structure, represented in procedural memory, and language-specific knowledge of the combinatorial constraints on structure-building, which are stored as part of the lexicon in declarative memory. Sentence structure is built incrementally using an extension of an established, computationally robust grammar theory, Lexical Functional Grammar (Bresnan, 1982). Using a single set of productions, together with a dual lexicon representing grammar fragments of English and Korean, the model is able to parse complex sentences in both languages, constructing syntactic representations that match human judgements. The model reproduces garden path phenomena reported by English and Korean native speakers, and introduces a cross-linguistic treatment of prosodic breaks to avoid garden-paths during processing. Limitations to the model are discussed, as well as questions that are currently under investigation.

The workload capacity of semantic search in convergent thinking

PO

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We employ Systems Factorial Technology (Townsend & Nozawa, 1995) to investigate how people combine dual cues in semantic memory search. Our aims are to understand: (1) how cues interact during the process of semantic search in convergent thinking, and (2) whether workload capacity (i.e. cue-processing efficiency) is related to the final search result. In two experiments, participants completed a typical convergent thinking test and a word production task. The results reveal that: (1) collective evidence presumably supports a parallel model despite individual differences in workload capacity, (2) there exists a negative correlation between workload capacity and performance on convergent thinking test. A potential explanation is that, for the creative individual, loading many candidate answers leads to consumption of substantial processing resources that shows as low workload capacity, but also allows creative individuals to switch more easily from one candidate to another so that they have a higher probability of successfully producing an answer within a limited time. Our results further imply that workload capacity is a significant factor for the semantic search process in convergent thinking and provides new insight on the model of semantic search and creativity.

Price discounts vs. awarding points – Verification of sales promotion effect in Japanese supermarkets

PO

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Senshu university, Japan

A frequent shoppers program is a sales promotion strategy used by retailers worldwide. Awarding points can be said to be similar to price discounts in the sense that a return for the amount of money. However, there are disadvantages to awarding points such as restriction of use, expiration date, and use after the next time. Price discount doesn't have this demerits. From a rational perspective, consumers should be more likely to prefer discounts than points. Which has the higher perceived value between price discounts and equivalent amount points? Regarding this, Nakagawa (2015) showed that the relationship between the perceived value of awarding points and price discounts is switched depending on the amount of purchase. This phenomenon can be explained by mental accounting theory (Thaler, 1985) and magnitude effect. Mental accounting theory is based on the value func-

tion of Prospect theory, and when the purchase amount is small, awarding points have higher perceived value than price discounts. Magnitude effect is an effect in which decision making and behavior change depending on the amount of money. When the Purchase amount is large, price discounts have higher perceived value than awarding points. Therefore, we investigated how the perceived value of price discounts and awarding points in a supermarket with changes in the purchase price. This study aims to detect the amount of money where switching subjects preference of price discounts and awarding points by fitting linear or non-linear regression models. As a result, it is possible to consider which sales promotion is effective for each amount.

Construction of a decision and learning model in repeated social dilemma games: Model evaluation using Bayesian statistical modeling

PO

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Several laboratory experiments of social dilemma game have provided robust data suggesting that the initially high cooperation rate declines as the game is repeated. However, changes in decision-making mechanisms that are responsible for this decline are not well understood. Although reinforcement learning models can explain changes in the cooperation rate from the perspective of evolution, they cannot explain the high initial cooperation rate and the subsequent decline. In this study, a decision-making model was derived from the social value orientation (SVO) model (Muto, 2006), and the expected utility of cooperation and non-cooperation was integrated into a learning model. Then, a laboratory experiment was conducted to test the model. The model comparison showed that the data were best explained by the model that considered learning from the perspective of the game's gain structure, including the marginal per capita of return (MPCR), and the cooperation of others. The results suggested the following: (1) Altruism, which is one of the parameters of SVO has a positive main effect on cooperation, whereas equality, which is the other parameter of SVO has an effect on cooperation only through the interaction with the expectations for cooperation by others; (2) MPCR is estimated to be high at the beginning of the game, and cooperation decrease as MPCR is perceived more accurately. (3) The impact of equality accelerates the decline in cooperation when the expectations for cooperation by others fall below 50% as a result of accurately estimating the MPCR.

Effects of speed on motor skill transfer

PO

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Our research aims to model human motor skill learning using a video game paradigm. We hereby evaluate the degree of motor skill transfer across game speeds and introduce changes that need to be made to the ACT-R architecture to model such

transfer. This work uses the Auto Orbit game in which a ship is orbiting around a balloon at a constant speed. The player needs to learn how to adjust the ship's aim and fire missiles at the balloon under temporal constraints. We had subjects learn to play the same game in slow, medium, and fast game speed conditions. We further explored effects of skill transfer across conditions to assess humans' and models' ability to adapt their motor behavior across speeds. To do so, we utilized an ABA experimental design including all 9 A-B pairs of game speeds (out of slow, medium, and fast speeds). Motor skill learning was evaluated using four experimental measures, with a focus on motor timing. These included a measure of keypress sequence regularity (Shannon entropy), motor timing variability (inter-shot interval logarithmic coefficient of variation), motor timing periodicity and motor timing regularity (both extracted using the shots autocorrelation function). Based on these measures, we first show that subjects were able to rapidly adapt to each game speed and adjust their firing rate accordingly. We then compare human and model motor skill learning and shot timing across speeds. Finally, we discuss our current model implementation and provide some ideas for future improvements.

Advantages of TERGM compared to Siena

PO

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Senshu University, Japan

In social psychology, group dynamics is one of the most important topics. To understand group dynamics, it is necessary to research the change of group network structure. There are two methods to analyze the group network data that evolve over time: TERGM (Hanneke et al. 2010; Krivitsky and Handcock 2014) and Siena (Snijders et al. 2010). TERGM (Temporal Exponential Random Graph Models) is an extension of ERGM to accommodate intertemporal dependence in longitudinally observed networks. It can use ERGM network terms and statistics to be reused in a dynamic context, understood in terms of formation and dissolution of edges. From network data at two or more points in time, Siena estimates that the network structure at the previous point in time affects the change in the relationship between actors at the later point in time by using agent-based simulations.In this study, we use TERGM and Siena to analyze similar network data and compare the results of each.Also, the advantages and disadvantages of each model will be identified.

Bayesian Approach to Belief Updating and Anxiety in the Classic Beads Task

PO

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The tendency to accept a hypothesis based on fewer than normal pieces of information ("Jumping-to-Conclusions" (JTC) bias) is a probabilistic reasoning bias commonly observed in clinical populations with delusions. This tendency can be attributed to a relatively low decision threshold and overweighting of a piece of evidence. Whilst some highly anxious individuals demonstrate JTC bias, the implications of findings

remain contentious. The contention stems from a lack of understanding about how anxiety interacts with the two factors in belief updating. It remains unexplored as to whether anxious individuals deviate from rationality in belief updating just as much as the healthy population or are simply less "over-cautious" in gathering information. The present study adopts a systematic approach utilising a Bayesian graphical model to answer these questions. Based on the classic beads task, the model illustrates how a rational agent would update their prior belief upon receiving new information and at what point that updated belief would cause them to act. Then, we investigate the impact of anxiety on decision threshold and evidence weights in the model, and eventually how belief updating would change. These steps allow for comparisons between a rational response and those exhibited by both healthy and anxious populations. By clearly illustrating the influence of anxiety on each parameter in the model, we can deepen the understanding of associations between anxiety and JTC bias. The properties of the model are demonstrated in a series of simulation studies. The implication of this model on real-life data will also be discussed.

Understand response bias: a threat to measurement validity and measurement equivalence

PO

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Rating scales are commonly used in psychological surveys to elicit respondents' judgements. However, the presence of response bias will threat the validity of result in surveys. Response bias (RB) refer to the cases where the number of certain response options was disproportionately more than others. The causes of RB consist of both respondent factors (such as personality or cultural influence) and context-dependent factors (such as scale format or nature of contents). The results before and after controlling for RB can be completely different. This study aimed to investigate the influences of RB. A series of simulation studies was carried out to explore the influence of RB on means, variances and associations across different conditions. The influence of RB on variables was evaluated by several indicators, including bias in estimation and variance ratios. Results showed that the influence of RB depended on the shapes of distributions of the variables. In addition, we used the data from the World Value Survey (WVS) Wave 6 to demonstrate how RB could influence means, variances and associations among variables in real world. We found that RB had substantially differing impacts on the means, variances and distribution shapes of the WVS data across different countries. Taken together, the simulation results and WVS findings indicate that RB can be a major challenge for measurement validity and measurement equivalence in studies using rating scales. We discuss implications and recommendations to researchers.

Are Facial Identity and Expression Perceived Independently? A Study Controlling Stimulus and Decisional Confounds

PO

Hosseini, S. Sanaz; Soto, Fabian

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Numerous studies have investigated processing of emotional expressions and facial identity and the possible integrality between the two. However, the results of these studies have not come into an agreement on whether facial expression and identity are processed integrally or they are perceptually separable, which may be due to a general lack of control of stimulus and decisional factors. This makes it necessary to develop experiments that overcome the shortcomings of the previous research and may shed light on this debate. In this study, we performed an experiment with highly controlled stimuli using 3-D realistic computer-generated faces for which the discriminability of identities and expressions, the intensity of the expressions, and low-level features of the faces were controlled. A large number of participants, distributed across twelve experiments, performed identification tasks for the six basic emotional expressions and the neutral expression. General recognition theory with individual differences was utilized to model the data, which allowed us to dissociate between perceptual and decisional processes. Results showed robust violations of perceptual independence and decisional separability, which were consistent across most experiments. Perceptual separability results were inconsistent for most expressions, except for the case of happiness and anger. Anger was exceptional in that it showed perceptual separability from identity, and vice-versa. Happiness was perceptually separable from identity, but not vice-versa. Interestingly, discriminability of identity was consistently reduced by happiness compared to a neutral expression.

Predictions of REM Model on the Null List-Strength Effect in Source Recognition

PO

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The strength-based mirror effect in recognition memory is the finding observed as an increase in hits and a decrease in false alarms after an additional study. When a set of items is strengthened in a list in which another set is not, recognition memory performance of weak items is not negatively affected by being studied along with strong items. This finding is defined as the null list-strength effect and both of these findings are explained by the differentiation mechanism. Currently the study conducted by the researchers examined the list-strength paradigm in source memory by adopting a recognition task, and demonstrated a strength-based mirror effect and a null list-strength effect in source memory. Following these finding in source recognition memory, predictions of the Retrieving Effectively from Memory model would be explored to understand the underlying processes.

Joint modelling group differences from military personnel

PO

Innes, Reilly; Brown, Scott

University of Newcastle, Australia

With recent advances in computational modelling techniques, joint modelling of behavioural tasks has become more accessible. In the current experiment, results from a dual task cognitive workload paradigm were compared across two groups. The two groups were student participants and a highly skilled military group who were in a selection program. Both groups completed a multiple object tracking task (MOT) and a simultaneous detection response task (DRT). We then jointly estimated parameters for models corresponding to the decisions in the MOT and responses to the DRT using a Particle Metropolis within Gibbs sampling method, separately for each group. We use the Linear Ballistic Accumulator to model decisions in the MOT and the shifted-Wald to fit responses in the DRT. MOT results showed a large difference between the groups on accuracy, with an interaction effect observed between groups and level of difficulty in response times, where military group response times slowed at a greater rate than the student group. In the DRT, the military group responded faster and with greater accuracy than the student group. Model results indicated the military group were more cautious than students, and tended to have faster processing speeds. Our findings show the strength of new sampling methodologies in not only explaining decision making strategies, but also in evaluating correlations between model parameters, within and across tasks.

Hierarchical Bayesian parameter estimation with the Particle Metropolis within Gibbs sampler

PO

Cooper, Gavin; Cavallaro, Jon-Paul; Innes, Reilly; Kuhne, Caroline; Hawkins, Guy; Brown, Scott

University of Newcastle, Australia

Hierarchical Bayesian techniques have proven to be a powerful tool for the estimation of model parameters and individual random effects. However many existing methods for estimating in this way are extensions to previously used methods, and therefore are not necessarily efficient for this purpose. I present an implementation in R of a new sampler based on the paper by Gunawan et al. (2020, JMP). This new approach has the benefit of being built for hierarchical estimation from the ground up and is easily parallelized. Additionally it allows for the estimation of the full parameter covariance matrix, providing the ability to model two tasks jointly and directly estimate correlations between parameters in the two tasks.The poster will provide an introduction to the approach, a brief overview of important use cases for the sampler and a short tutorial on using the package. References to more detailed information and how to access the package will also be provided.

Evaluating the speed of different approximations to the density function of the diffusion decision model

PO

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The diffusion decision model (DDM) is the most prominent model for jointly modelling binary responses and associated response times. One hurdle in estimating the DDM is that the probability density function contains an infinite sum for which several different approximations exist. The goal of this project is to compare which of these approximations is the fastest given parameter values that are typically encountered when fitting the DDM. To this end, we implemented all existing approximations as well as some new combinations of existing methods in C++ and provided an interface to R via Rcpp. This enabled us not only to evaluate each approximation in an equal environment but also to utilize the faster C++ language while maintaining the R language interface. Using a benchmark approach, we compared the speed of all approximations against each other (as well as against some existing R implementations). The results of these benchmarks show that approximations that switch between the so-called small-time and large-time approximation based on input response time and parameter values are on average fastest, especially when combined with fast implementations of the small-time approximation. In addition, our new C++ implementations are faster than all existing implementations, even when including variability in the drift rate.

A Neurocomputational model of hippocampal field CA1 during context fear conditioning

PO

Narasiwodeyar, Sanjay; Soto, Fabian

Florida International University, United States of America

The Hippocampus is a cortical structure involved in a variety of learning and memory tasks. Hippocampus is most vital, however, for performing tasks that involve rapid learning of complex stimuli. One such task is the contextual fear conditioning paradigm (CFC). Although there is a plethora of evidence linking the hippocampus to CFC tasks, the precise mechanistic function of the Hippocampus during CFC remains elusive. A close inspection of the distinct input and output pathways of the hippocampus reveals that sub-field CA1 might serve as a critical junction where contextual fear memories are stored and organized. Recent evidence also suggests that the prefrontal cortex exerts top-down cognitive control over memory formation in CA1, via the Nucleus Reuniens (NR). We present a neurocomputational model of field CA1 that takes into account the various inputs to the region, including NR inputs to inhibitory CA1 inter-neurons, which control the specificity of memory encoding in CA1. We use spiking neuron and synaptic plasticity equations that are more neurobiologically-realistic than those used in previous models. Simulations with the model suggest a distinct role for the Nucleus Reuniens input in separating representations of highly similar events. Furthermore, the model explains recent

experimental results relating the role of PFC inputs to CA1 in controlling generalization of fear memories in the CFC paradigm.

Search Strategies in Multiattribute choice using Bayesian Belief Updating

PO

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This project examines how people learn strategies of multi-attribute decision making in an unfamiliar environment where they must learn two important properties of cues: the discriminability (i.e., the proportion of occasions where a cue has different values for a pair of options) and validity (i.e., the probability a cue identifies the correct option when a discrimination occurs). In the past, most researchers have looked at how known or guessable values of discriminability and validity relate to search and stopping decision rules. We try to understand how humans formulate search and stopping rules when they do not know the underlying discriminability and validity of cues, but must learn these over time. We model behavior using a Bayesian model where beliefs of the underlying validity and discriminability of cues are updated based on every observation made by the participant (Mistry, Lee, & Newell, 2016). We use the beliefs about discriminability and validity obtained from the Bayesian model to define different search strategies that participants might use in the task. In order to link beliefs to search strategies, we use sampling procedures where samples are drawn from the belief distributions and used to order cues for search. We test our models on data collected from human subjects and show that the modeling results intuitively map onto behavioral findings from the experiment

Applying Cognitive Models to Evaluate Bias in Expert Predictions for NFL Games

PO

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Standard signal detection theory (SDT) models use an unbiased criterion as a comparison point. But, in some situations, the unbiased criterion is not the right reference point to measure bias in decision making. We consider the context of experts predicting the winning team in a National Football League (NFL) game. An unbiased criterion assumes that the home and away teams have equal probabilities of winning and that any partiality toward the home team over the away team is detrimental. However, the home team advantage exists, as evidenced by the behavior of betting markets and home teams having won 58% of the games throughout the 1981-1996 NFL seasons (Vergin & Sosik, 1999). Altogether, this suggests that experts should have some partiality toward the home team to improve their prediction accuracy. We apply hierarchical SDT models to expert predictions provided by nflpickwatch.com for the 2014-2019 NFL regular seasons to measure various forms of bias in predictions. In particular, we use the SDT framework to evaluate expert bias in terms of home team advantage, the cumulative win-loss record of teams,

and herding by making the same prediction as other experts. Applying our model provides a way of measuring the extent to which experts are under- or over-reliant on these different sorts of biases when they make predictions.

Sensitivity vs. awareness curve: a novel model-based analysis to uncover the processes underlying nonconscious perception

PO

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We present a novel model-based analysis of the association between awareness and perceptual processing based on a multidimensional version of signal detection theory (general recognition theory, or GRT). The analysis fits a GRT model to behavioral data and uses the estimated model to construct a sensitivity vs. awareness (SvA) curve, representing sensitivity in the discrimination task at each value of relative likelihood of awareness. This approach treats awareness as a continuum rather than a dichotomy, but also provides an objective benchmark for low likelihood of awareness. In two experiments, we assessed nonconscious facial expression recognition using SvA curves in a condition in which emotional faces (fearful vs. neutral) were rendered invisible using continuous flash suppression (CFS) for 500 (Experiment 1) and 700 (Experiment 2) milliseconds. Participants had to provide subjective awareness reports, expression discrimination responses, and metacognitive judgements of confidence on those discrimination responses. We predicted and found evidence for the nonconscious processing of facial expression, in the form of higher than chance-level sensitivity in the area of low likelihood of awareness. We also found evidence for metacognitive sensitivity in the absence of awareness. The similarity between the pattern of results from perceptual discrimination and metacognitive judgements is in line with the detection-theoretic assumption that both processes are based on the same perceptual evidence variable. To the best of our knowledge, this is the first objective and bias-free demonstration of nonconscious perceptual processing of facial expression.

Using Cognitive Diagnostic Modeling to Investigate Learning Taxonomy Assumptions

PO

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Bloom's Taxonomy (BT) (Bloom, 1956) and Bloom's Revised Taxonomy (BRT) (Anderson et al., 2001) are widely used to guide the design and evaluation of learning assessments, but few studies have investigated the underlying assumptions of such taxonomies. Data from two undergraduate social psychology multiple-choice exams were analyzed using CDM. One exam was 33 questions and taken by 86 students, and the other exam was 58 questions and taken by 47 students. We used key words in exam questions to sort them into one of the skill categories that constitute the "understanding" rung of BRT's cognitive processes hierarchy: "Explaining" ("E"),

"Classifying/Comparing" ("CC"), or "Inferring/Interpreting" ("II"). Next, we specified two Deterministic Noisy Input And (DINA) models, which predict the probability of correctly answering an exam question. The "Exclusive Resources" (ER) model assumed items required only the latent skill corresponding to its category. The second model, a "Shared Resources" (SR) model representative of BRT, included the additional specification that all items require a common latent skill. Both the BIC (Bayesian Information Criterion) and sampling error were estimated using nonparametric bootstrapping methods, and the Bayes Factor (BF) was calculated from the average BICs. The BF analysis indicated that the ER model was more likely than the SR model for both exams. These findings contradict a foundational assumption of BT and BRT that higher-order inference involving explaining, classifying/comparing, and inferring/interpreting requires the existence of a shared latent skill (e.g., remembering). The relevance of this methodology for evaluating learning taxonomy assumptions using CDMs is discussed.

Learning to Learn: Modeling the time-course of visuomotor adaptation

PO

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Across 640 training trials, participants using a computer tablet learned to move a cursor that had its movement direction rotated by 90 degrees relative to on-screen visual feedback. These training trials involved either an all-at-once "sudden" rotation to 90 degrees starting at trial 1 or a "gradual" rotation in nine separate increments of 10 degrees. Similar prior work found a larger detrimental aftereffect when transferring back to no rotation following gradual adaptation training. We replicated this effect and crossed these conditions with a speed/accuracy emphasis manipulation. To characterize the nature of learning during training, we applied a simple two-parameter learning model to trial-by-trial errors in motion direction. One parameter captured the learning rate, reflecting trial-to-trial adjustments based on the difference between predicted and observed rotation. The other parameter captured memory, reflecting a tendency to use the estimate of rotation from the previous trial. This simple model captured individual differences, speed/accuracy emphasis, and subtle differences between the sudden and gradual training regimes. Furthermore, the model correctly predicted transfer performance for the gradual condition. However, it grossly over-estimated transfer errors for the sudden condition. We hypothesize that participants in the sudden condition learned that the mapping between movements and visual feedback can abruptly change (i.e., a change of environment, rather than visuomotor adaptation), allowing them to quickly adopt a new visuomotor mapping in the transfer phase when the rotation was removed. This learning-to-learn in the sudden condition may reflect model-based forms of reinforcement learning, in contrast to trial-and-error model-free learning.

Evaluating EEG activity as predictive of memory through classifiers

PO

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Brain-activity measures have the potential to provide powerful new constraints on memory models. With classifier-based approaches, one can identify signals, derived from a training-set data, that can predict memory outcome on test-set data. Advancing beyond descriptive methods, the classifier-based approach could identify brain-activity features that are more likely to be behaviourally relevant, rather than spectator or performance-irrelevant processes. Instead of chasing down optimal classification, we take a systematic approach to evaluate this, and to identify where improvements to classifier approaches could be made. We start with univariate event-related potential measures that have previously been implicated in recognition-memory study and matching processes (study: LPC and slow wave; test: FN400 and LPP). In 64 participants performing old/new verbal recognition, univariate measures predicted memory-accuracy with small, but significant, success (95% CI AUC = study: [0.51 0.54]; test: [0.52 0.55]; chance=0.5). Multivariate, LDA and SVM spatio-temporal classifiers performed better (study: [0.52 0.56]; test: [0.55 0.60]), suggesting the importance of other features beyond these previously identified ERP features. Overall success rates remained remarkably low, but this is in line with results from other related published approaches. However, AUC approached 0.7 for high-performing participants. Addressing individual differences in motivation/engagement, or titrating difficulty, may lead to high classification success. Future approaches should also incorporate the myriad known behavioural factors that determine memory outcome but are absent in brain activity during study or test of a particular item.

Are Supernatural Concepts Epiphenomenal?

PO

Sommer, Joseph; King, Nicole; Hemmer, Pernille; Musolino, Julien

Rutgers University, United States of America

A leading idea in the literature on the cognitive science of religion is that supernatural concepts (e.g., gods, ghosts, spirits) are memorable because they are minimally counterintuitive (MCI) – i.e., they contain a small number of violations of ontological assumptions. These violations increase the salience of the resulting concepts but because their number remains low, they only minimally complicate the concepts' inferential structure. Consequently, MCI items are regarded as optimal for memory and are therefore prime candidates for cultural transmission. Interestingly, this phenomenon is reminiscent of the von Restorff effect (VR) which describes a pattern of enhanced memorability for outlier items in a homogeneous list. We therefore ask whether the MCI and VR effects may be behavioral manifestations of the same underlying cognitive processes. To permit a meaningful comparison of the two effects, we developed a novel set of stimuli to guard against a number of existing confounds. We objectively measured and normed for a number of relevant parameters by ob-

taining ratings from a large M-Turk sample. We then conducted an experiment to assess the relative memorability of MCI and VR items compared to intuitive (INT) controls. Results indicate that MCI and VR items are both recalled better than INT concepts, but, crucially, that MCI items do not possess a memorability advantage over VR items. Furthermore, results from additional conditions suggest that the benefit of minimal counterintuitiveness is not confined to supernatural concepts. We argue that this evidence supports a single mechanism underlying both the MCI and VR effects.

Creative or Not? Bayesian Hierarchical Diffusion Modeling of the Evaluation Phase of the Creative Process

PO

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How do people evaluate whether an idea is creative or not? It is commonly assumed that creative ideas have two characteristics: they are original as well as useful. However, research suggests that, overall, people value originality more than utility when they judge whether something is creative or not. But individuals may also differ in how much they value originality and utility in their creativity judgments. In the extreme, some individuals may take utility into account while others do not at all. To examine conceptions of creativity in a standardized way and to explore individual differences, we used the creative-or-not (CON) task, a timed two-choice decision-making task. In this task, participants decide whether they find uses for certain objects creative or not (e.g., using a book as a buoy). The different use items vary on the two dimensions 'originality' and 'utility'. We analyzed the CON task data using a Bayesian hierarchical diffusion model. In a sample of university students ($n = 293$; 17806 trials) we found, as expected, that originality and utility of the use items influences the drift rate of the diffusion model but that the effect of originality is greater. This suggests that, on average, people take originality and utility into account when they evaluate creativity, but that originality is considered more important than utility. In addition, we find substantial individual differences. The more individuals took originality into account when evaluating creativity, the less they took utility into account and vice versa.

Converting continuous tracking data to pseudo response time distributions

PO

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Analysis (and models) of response times typically rely on data from trial-by-trial designs, whereby experimental tasks present participants with a series of trials constructed as a sequence of stimulus presentation, response, and a short break, and all over again. However, real-world behaviours (e.g., driving) often require continuous monitoring of information and accompanied by ongoing responses. In these cases, there is no start and end to a trial, and the researcher cannot measure

RT, pre-empting many successful approaches to analysis of RT data (such as Systems Factorial Technology, on which we focus here). We developed and tested a novel technique for converting continuous tracking data to a trial-like form, producing what we call 'pseudo response times'. These pseudo response times can be conveniently subjected to many existing RT analysis techniques. Participants completed a continuous tracking task. We calculated the absolute tracking error as the distance between the user-controlled needle and to-be-tracked target. We then converted these data to pseudo RTs by setting a threshold of maximum acceptable tracking error, identifying points in the time series when tracking error crossed this threshold, and calculating the time taken to return to acceptable performance. Analyses of pseudo RTs agreed with equivalent analyses of mean tracking error, albeit with less sensitivity.

Diagnosing Short-term Memory Scanning Using The Systems Factorial Technology – Replication Studies

PO

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Townsend and Fific (2004) published an influential short-term memory (STM) study in which they observed individual differences in serial and parallel STM scanning. The authors employed the systems factorial technology – the novel methodology which provides strong diagnostic tests of cognitive architectures, and presented a new method of manipulating probe-to-memory item processing speed for memory loads $N = 2$. Three variables were manipulated in this experiment: number of processing elements ($N = 2$), phonemic dissimilarity of a target to the particular memorized item (high, low) and duration between the memorized set and a target (short-long). In the original study 10 subjects participated in about 20 sessions each. In the current research we conducted a conceptual replication of the original study: two hundred subjects participated in 1 session each, and novel memory load conditions N=1 was included. The results added a converging evidence in testing serial/parallel processing in short-term memory scanning.

Intentional binding: an unintentional artifact?

PO

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The sense of agency (SoA) is a fundamental aspect of the human experience. Intentional Binding (IB), the subjective compression of the time interval between a voluntary action and its associated outcome, has been proposed as an implicit measure of SoA. Given the fundamental nature of SoA, one would expect the presence of IB in all healthy individuals. To date, empirical investigations of IB have only reported aggregate data averaged across individuals and may inappropriately use parametric statistics on non-normally distributed data. We compared aggregate vs. individual data in a study ($N = 35$) using a variation on the standard IB paradigm. Aggregate results replicated the expected effect of action binding ($F(1, 28) = 4.44$,

$p = 0.044$) and outcome binding ($F(1, 35) = 49.12$, $p < 0.001$). Crucially, however, inter-individual analyses revealed that more than half of participants' mean binding values for either action or outcome ($N = 20$) were in the opposite of the expected direction, in line with results from involuntary action conditions in the literature. Moreover, reanalysis of a publicly available data set shows a similar pattern; the authors reported a replication of the standard IB effect at the aggregate level but our re-analysis at the individual level revealed 19 out of 20 participants in certain sub-conditions had mean action or outcome binding values in the opposite of the expected direction. These findings indicate the IB phenomenon may be another classic example of how averaging can be misleading and will have important implications for the future of research in this domain.

Emergence of Hierarchical Versus Similarity Relations in Known Categories

PO

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The structure of organized categories is argued to be hierarchical and is suggestive of the taxonomy of the "superordinate-basic-subordinate" categorization schema (Rosch, 1978). In contrast, the similarity of a member to its category may also be indicative of the extent of transitivity that exists within a category. To investigate the role that hierarchical and similarity relations contribute to categorization [adapted from Sloman (1998)], we asked 49 participants to evaluate the probability of a conclusion statement based on the given fact. In condition 1, participants were only provided a fact and conclusion, while in condition 2 participants were also provided with a hierarchical relation (e.g., All pines are wood; Fact: All 'wood' is fibrous; Conclusion: All 'pine' is fibrous). Condition 1 can be solved using hierarchical relations, while condition 2, an inductive reasoning task, can be solved with similarity or hierarchical relations. We used 20 natural and 20 artificial categories validated by Gruenenfelder (1984), with typical and atypical examples in each category. A factorial ANOVA revealed a main effect of condition, $F(1, 48) = 69.53$, $p < 0.001$, indicating that providing hierarchical relations increased overall agreement between fact and conclusion. We also found the expected main effect of typicality, $F(1, 48) = 45.39$, $p < 0.001$. An interaction between condition and typicality was also detected, $F(1, 48) = 4.79$, $p = 0.034$, however, a metric multidimensional scaling of average ratings per category for conditions 1 and 2 showed that agreement between the fact and conclusion might rely on the type of category rather than typicality.

Modelling emotion and cognitive processing in dementia

PO

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Frontotemporal Dementia (FTD) is an umbrella term to describe younger onset dementias with clinical presentations arising from progressive neurodegeneration

of the frontal and temporal brain regions. Patients diagnosed with FTD show disturbance of emotion processing due to pathological changes affecting the network. FTD, therefore, provide a useful framework to understand the underlying mechanisms of emotion processing. Furthermore, establishing clinical diagnose in dementia cases early step often result in inaccurate diagnose due to overlapping syndromes.The practical aim of this study is to inform us about which tests are more specific and sensitive to differentiate FTD from other dementia such as AD. Considering that few AD patients, although having a primarily cognitive problem (i.e., episodic memory), often present emotion processing problem.This project applied novel methods using data-driven analysis to model emotion processing and the contributing factors such as general cognitive. Elementary analysis shows that combining emotion and cognition tests can differentiate bvFTD from AD. Further analysis investigated the unique pattern of emotion-cognition interactions between FTD and AD. These results give a better understanding of how emotion and processing deficits occur in dementia.

Causal structure learning and exact inference: A study of conditions for ideally Bayesian behavior in human learners

PO

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According to previous studies, people generally do not perform exact Bayesian inference in causal structure learning. However, there are conditions when a reasonable strategy might be to compute exact posterior probabilities: evidence arrives one piece at a time, learners do not have access to previous information, and a problem at hand has a sufficiently small hypothesis space. We conducted a series of experiments to test whether these conditions would result in a preference of exact inference in humans. A non-deterministic causal system of four binary elements was employed, and participants were sequentially presented with the system's states (evidence). As a new state was presented, participants were asked to indicate the most probable scheme of causal connections (hypothesis) in the system given this state and those demonstrated previously. We used two sizes of hypothesis space: two and six schemes of connections. We compared participants' responses to the limited memory (LM) Bayesian model (posterior re-estimation based on several recent states) and the ideal Bayesian model. Additionally, participants' responses were compared to the LM "win-stay, lose-sample" (WSLS) model. When hypothesis space was small, participants preferred the probability-based strategy (described by the ideal Bayesian, thus matching exact inference) as it was more optimal in terms of memory to retain posterior probabilities, not evidence. When hypothesis space size increased, participants often resorted to the evidence-based strategy (described by the LM Bayesian) as it became difficult to memorize exact probabilities. Additionally, we found that most participants revealed strong WSLS tendencies across all conditions of our experiments.

Hierarchical Bayesian Psychometric Curves Reveal Mechanisms of The Vigilance Decrement

PO

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A vigilance task requires observers to monitor for rare signals over long periods of time. The vigilance decrement is a decrease in detection rate that occurs with time on task, sometimes beginning within 5 minutes. Signal detection analyses have ascribed the decrement to changes of response bias or declines of perceptual sensitivity. However, recent work has suggested that sensitivity losses in vigilance are spurious, and that the decrement instead results from attentional lapses.Analysis of psychometric curves provides a way of isolating changes in bias, sensitivity, and lapse rate. Because signal events are rare and trials are partitioned into brief blocks, though, a standard vigilance task does not provide enough data to fit psychometric curves for individual observers. To circumvent this problem, we used hierarchical Bayesian modeling to combine data from a large number of individuals. Participants ($N = 99$) performed a 20-min vigilance task that required them to judge whether the gap between two probe dots each trial exceeded a criterion value. Signal detectability was manipulated via the method of constant stimuli. Hierarchical psychometric curves were fit to data from the first and last 4-minute blocks of trials. Model fits revealed three changes between blocks: a conservative shift of response bias, a decrease in perceptual sensitivity, and an increase in response lapse rate. Results confirm that sensitivity losses are possible in a sustained attention task, but indicate that mental lapses can also contribute to the vigilance decrement.

Reading, eyetracking, and diagnostics

PO

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Recent estimations show that 10 per cent of children population of Argentina suffers of Specific Learning Disorder (SLD). Attention disorders and SLD present, generally, large comorbidity making difficult to distinguish them clinically, in a quantitative way. In Argentina, the diagnosis of these disorders is performed by neurologists, basing on neuro-psychological evaluations performed by psycho-pedagogues. It is the aim of our studies to add or enhance the already existent tools based on the inclusion of physiological magnitudes. The eye movements can serve as a direct source of information about what is happening in the brain (Luna, Velanova, & Geier, 2008). Track the eyes of children while reading, gives a great amount of data to study the way reading is being process (Kliegl, Nuthmann, & Engbert, 2006). Analyzing statistically the data, permits to obtain the number of fixation, the fixation duration, the saccade amplitude, among other other metrics (Duchowski, 2002). However more sophisticated quantities like reading speed processing can be also

generated. In this work, we present the results of studies related to reading. We registered neurotypical and dyslexic children eye movements while reading. We process mathematically the data with the objective of introducing variables allowing clearly differentiate between both groups.

Using a Bidirectional Associative Memory and Feature Extraction to model Nonlinear Exploitation Problems

PO

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Each day we are faced with a decision of maximizing our resources by using our current knowledge to learn new things. Should we go to the new restaurant that just opened around the corner or stick to an old, reliable favourite? This is known as the exploration-exploitation dilemma and it is at the heart of reinforcement learning. The present study looks at the exploitation half of this problem and aims to implement it in a biologically plausible recurrent associative memory model. In the framework of Artificial Neural Networks, exploitation is observed when the network can iterate through many learned responses and stabilize on the correct one to solve a given task. This is a process akin to being able to switch from a line to a point attractor. More precisely, Bidirectional Associative Memory (BAM) is used to accomplish such tasks where the context dictates which attractor the network should converge to. For simple independent tasks, the BAM is sufficient. However, for overlapping tasks, the task becomes nonlinearly separable. Therefore, the BAM needs an extra unsupervised layer to extract unique features from the inputs. These features combined with input are then sent to BAM where it can learn the different attractors adequately. This network was able to stabilize on the correct responses of tasks that involved time series of varying lengths, overlap, and levels of correlation; the variability one would expect from the real world.

Missed One! How Ballot Layout and Visual Task Strategy Can Interact to Produce Voting Errors

PO

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Rice University

This paper presents an ACT-R model designed to simulate voting behavior on full-face paper ballots. The model implements a non-standard voting strategy: the strategy votes first from left to right on a ballot and then from top to bottom. We ran this model on 6600 randomly-generated ballots governed by three different variables that affected the visual layout of the ballot. The findings suggest that our model's error behavior is emergent and sensitive to ballot structure. These results represent an important step towards our goal of creating a software tool capable of identifying bad ballot design.

Computational Modeling of Human Social Intelligence and Communication

PO

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The next level in understanding human social cognition is to model it comprehensively. To this end, we have been developing a framework and model that takes as input an event involving someone (focusing on who it was and what they did), and assesses the event based on whether it should change social accounting among individuals, and whether something should be done, such as communicating with others. Here, we present development of the model computationally and results generated by it as predictions to be tested empirically: e.g., more communication about those socially close to us when their actions are positive, and more about those with higher status (i.e., celebrities) when negative; and the relative merit or egregiousness of a wide range of behavior. Leveraging what is known of the human social mind and brain, our work aims to provide a comprehensive model of human social cognition.

Feedback Influences Syllogistic Strategy: An Analysis based on Joint Nonnegative Matrix Factorization

PO

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Feedback for drawn inferences can lead to an adaption of future responses and underlying cognitive mechanisms. This article presents a reanalysis of recent hypothesis-driven experiments in syllogistic reasoning in which participants were presented with different feedback conditions (no feedback, 1s, 10s). We extend the original analysis, which only focused on no feedback vs. 1s feedback, by including the additional 10s condition. For our analysis, we rely on the data-driven theory- and hypothesis-agnostic Joint Nonnegative Matrix Factorization which allows us to contrast data sets based on the extraction of response patterns reflecting common and distinct response behavior. Our results support the previous claims that feedback does not generally boost logical reasoning ability but reduces the influence of biases against the response indicating that nothing logically follows from the premises.

Extending TransSet: An Individualized Model for Human Syllogistic Reasoning

PO

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Recently, the TransSet model for human syllogistic reasoning was introduced and shown to outperform the previous state of the art in terms of predictive performance. In this article, we pick up the TransSet model and extend it to allow for capturing individual differences with respect to the conclusion "No Valid Conclusion" indicating that no logically correct conclusion can be derived from a problem's premises. Our evaluation is based on a coverage analysis in which a model's ability to capture individuals in terms of its parameters is assessed. We show that TransSet also outperforms state-of-the-art models on the basis of individuals and provide further evidence for the existence of an NVC aversion bias in human syllogistic reasoning.

A Study in Activation: Towards a Common Lexicon and Functional Taxonomy in Cognitive Architectures

PO

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Activation has become a pervasive concept in many scientific disciplines, including cognitive and neural modeling, and AI. Unfortunately, its applications and functions are so broad and varied that it is difficult for practitioners to discuss the topic in precise and meaningful ways. This is particularly apparent in cognitive architectures, where a wider breadth of activation's utilities and forms have been explored. To help combat these terminological difficulties, and hopefully facilitate productive discourse and the development of future applications, we introduce (1) a lexicon of activation-related concepts, and (2) a functional taxonomy that enumerates many activation-related "design patterns" that have appeared in cognitive architectures. We demonstrate our taxonomy by applying it to the LIDA cognitive architecture, which includes one of the most varied and comprehensive adoptions of activation-related functionality.

Cognitivemodels – an Extendable R Software Package to Develop and Test Cognitive Models

PO

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We present the software package cognitivemodels, a tool to build, apply, estimate, test, and develop computational cognitive models in R. The free package is designed

for coding efficiency, robustness, and flexibility and offers novice modelers a user-friendly front-end to use models and experienced modelers a powerful back-end to write models. Here, we show how the package implements the generalized context model (Nosofsky, 1986) and cumulative prospect theory (Tversky & Kahneman, 1992) and how end users can write further models with the package. We further present the package's variety of goodness-of-fit measures (e.g., binomial or normal log likelihood, mean-squared error, or accuracy), parameter constraints (linear constraints, box constraints, equality constraints, fixed parameters), optimization routines (e.g., Nelder-Mead), and choice rules (e.g., soft-max, epsilon greedy, or Luce's choice rule). We believe the package makes cognitive modeling more widely accessible and adds to robust model development.

A Computational Cognitive Model of Reasoning in Tibetan Buddhist Monastic Debate

PO

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In Tibetan monasteries, the education system relies heavily on a very specific style of debating that is at once exhilarating and intellectually rigorous. Relatively little research has been done on the psychological and neural mechanisms of this debate, which may be an interesting method for education around the world. Hence the formation of a theory of this practice is important. Here we present a computational theory of Tibetan monastic debate implemented in the ACT-R cognitive architecture. We complement the ACT-R model with graph theory to represent knowledge and show how we can capture the dynamic flow of a debate in our model. Future research should validate the model in its native population and enrich it with more detailed strategies. Nevertheless, we think it provides an interesting example of how the interactive process of debating can be modelled.

Modeling the Absence of Framing Effect in an Experience-based COVID-19 Disease Problem

PO

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Prior research in decisions from experience (DFE) has investigated people's consequential decisions after information search both experimentally and computationally. However, prior DFE research has yet to explore how computational cognitive models and their mechanisms could explain the effects of problem framing in experience. The primary objective of this paper is to address this literature gap and develop Instance-based Learning Theory (IBLT) models on the effects of problem framing. Human data was collected on a modified form of the Asian disease problem posed about the COVID-19 pandemic across two between-subject conditions: gain ($N = 40$) and loss ($N = 40$). The COVID-19 problem was presented as "lives saved" in the gain condition and "lives lost" in the loss condition. Results revealed the absence of the classical framing effect, exhibiting no preference reversal between gain and loss conditions in experience. Next, an IBL model was developed and calibrated to the data obtained in the gain and loss problems. The calibrated model was generalized to the non-calibrated conditions (gain to loss and loss to gain). An IBL model with ACT-R default parameters was also generalized. Results revealed that the IBL model with calibrated parameters explained human choices more accurately compared to the IBL model with ACT-R default parameters. Also, participants showed greater reliance on recency and frequency of outcomes and less variability in their choices across both gain and loss conditions. We highlight the main implications of our findings for the cognitive modeling community.

A Cognitive Model of Sound Representations in Children with Speech Sound Disorders

PO

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The goal of the current work is to develop a theoretical model which can possibly account for certain of the speech disarticulations that occur among children with Speech Sound Disorders (SSDs). In trying to do so, we propose an interface module, a specialized section within the mental realm, the nature and functioning of which may provide us with some useful insights on SSDs. The postulation of an interface module here is necessitated by the fact that there are facets of errors in SSDs and in typical populations that cannot be simply explained in terms of either articulatory/phonetic factors or matters pertaining to abstract sound representations. This paper will therefore present a detailed theoretical view of the interface, its nature, its relation with other levels in the mental space, and the functions it performs. The results of applying the proposed model to certain types of sound alterations in SSDs are described with implications for the cognitive representation of speech sounds.

Does ACT-R Model Me?

PO

Greve, Emily E; Reid, Elisabeth; West, Robert L.

Carleton University, Canada

We were interested in testing Newell's Micro Strategies hypothesis as well as assumptions made by both ACT-R and SGOMS theory using a mobile game and a predictive SGOMS-ACT-R model. The Model is designed to predict expert game play. We found in most conditions the model did predict the results, however in one condition the player employed an alternative Micro Strategy.

Ethical Test Driven Development: A Design Process for Building Ethical Agents

PO

Highstead, Thomas Steven; West, Robert L.; Schellinck, Jennifer; Esfandiari, Babak

Carleton University, Canada

As machines become autonomous, acting as agents within society, there will become an increasing need for them to interact with people. For a machine to act within a society free of its creator's supervision, it will also have to have the same capacity for intersubjective behavior as people. This paper presents a design system for creating a moral artificial agent based on cognitive modeling and test driven development.

A Biologically-Inspired Neural Implementation of Affect Control Theory

PO

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1: University of Waterloo, Canada; 2: National Research Council of Canada

Social interactions are a part of day-to-day life of most human beings. Affect, decision-making and behavior are central to it. With increase in adaptation of technology in our society, interaction between humans and artificially intelligent agents is also increasing. Large-scale brain-inspired neural models have been equipped with capabilities to fulfil a variety of tasks, but there has been relatively limited focus on making them capable of handling social interaction. In this paper, NeuroACT, a neural computational model and implementation of a socio-psychological theory called Affect Control Theory (ACT) is presented. This is towards building an emotionally intelligent AI agent, that can handle interactions. It takes as input a continuous affective interpretation of a perceived event, consisting of an actor, behavior and an object and generates post-event predictions of the next optimal behavior to minimize deflection. The aim is to model the role of affect guiding decision-making in AI agents, resulting in interactions that are similar to human interactions, while inhibiting some behaviors based on the social context.

Cognitive Flexibility in Cognitive Architecture: Simulate using Contextual Learning in PRIMs

PO

Ji, Yang; van Rij, Jacolien; Taatgen, Niels A.

University of Groningen, Netherlands, The

Biological systems are normally capable of adapting to given situations. Such flexibility ideally also needs to be a feature of any prospective cognitive architecture. Taken early language acquisition as an example, the quest for flexibility is explored here with the PRIMs (primitive element) architecture. Through contextual learning, a set of generally implemented primitive operations is capable of becoming selectively excited/inhibited to contextual buffer states that are continuously altered by the immediate perceptual inputs. Instead of deterministic programming for each of the tasks, this model simulates findings on a range of distinct infant language learning phenomena. This implementation provides one possible solution to achieve cognitive flexibility in a cognitive architecture.

Implementing Incentive Sensitization Theory of Addiction with Nengo Neural Network Simulator

PO

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We present first steps towards a biologically grounded implementation of the Incentive Sensitization Theory of addiction.We present multiple different plausible ways of mapping this theory into a computational model, and examine the resulting behaviour to see whether it accords with standard interpretations of the theory. This is the first step in a larger project to create a computationally tractible and biologically motivated model of addiction to help clarify and ground various terms in the theory.

The Effect of Task Fidelity on Learning Curves

PO

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1: Penn State, United States of America; 2: Charles River Analytics

What is the effect of level of simulation fidelity on learning and then on performance in the target task? We consider an example of a maintenance training system with two levels of fidelity: a high fidelity (HiFi) simulation that basically takes as much time as the real world task and a low fidelity (LoFi) system with minimal delays and many actions removed or reduced in fidelity and time. The LoFi simulation initially takes about one quarter of the time, and thus starts out getting about four times more practice trials in a given time period. The time to perform the task modifies the learning curves for each system. The LoFi curve has a lower intercept and a steeper

slope. For a small number of practice trials, this makes a significant difference. For longer time periods, the differences between low and high fidelity get smaller. Learners that move from low to high appear to not be adversely affected. We note factors, such as subtasks included, that could influence this transfer, and how this approach could be extended.

Joke Recommender System Using Humor Theory

PO

Agrawal, Soumya; Rayz, Julia Taylor

Purdue University, United States of America

In this paper, we propose a methodology that aims to develop a recommendation system for jokes by analyzing its text. This exploratory study focuses mainly on the General Theory of Verbal Humor and implements the knowledge resources defined by it to annotate the jokes. These annotations contain the characteristics of the jokes and hence are used to determine how alike the jokes are. We use Lin's similarity metric and Word2vec to calculate the similarity between different jokes. The jokes are then clustered hierarchically based on their similarity values for the recommendation. Finally, for multiple users, we compare our joke recommendations to those obtained by the Eigenstate algorithm which does not consider the content of the joke in its recommendation.

Drive the Bus

PO

Schwartz, David M. (1); Tehranchi, Farnaz (2); Ritter, Frank E. (1)

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ACT-R has been used to study human-computer interaction, however, up until the creation of JSegMan, ACT-R was unable to interact with unmodified interfaces not written in Common Lisp. Working with unmodified interfaces reveals deficiencies with ACT-R's motor module. Currently, ACT-R is capable of queuing rapid keystrokes, however, many programs require multiple keys to be pressed at once, which ACT-R cannot do. This prevents ACT-R from interacting with text editors such as Vim and Emacs. Similarly, ACT-R cannot model people playing many modern video games that require pressing multiple WASD or arrow keys at once while moving the mouse. This paper creates a model that demonstrates this deficiency while playing Desert Bus. Furthermore, new systems to allow parallel motor actions to be learned and requested are proposed and the implications of running a model over many hours is explored.

Characterizing Human vs Machine Gameplay in StarCraft II

PO

Peters, Chad A.; Esfandiari, Babak; West, Robert L.

Carleton University, Canada

Our research presents a review of the StarCraft II ecosystem, and an analysis of those universal characteristics integral to the replay data generated by thousands of humans and robots in mixed competitions. In this paper we present the obvious and subtle differences between human and machine tournament play, and demonstrate that we can still identify and leverage various aspects of game play to distinguish human from machine.

Re-Implementing a Dynamic Field Theory Model of Mental Maps using Python and Nengo

PO

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1: University of Freiburg, Germany; 2: University of Waterloo, Canada

In Dynamic Field Theory (DFT) cognition is modeled as the interaction of a complex dynamical system. The connection to the brain is established by smaller parts of this system, neural fields, that mimic the behavior of neuron populations. We reimplemented a spatial reasoning model from DFT in Python using the Nengo framework in order to provide a more flexible implementation, and to facilitate future research on a more general comparison between DFT and the Neural Engineering Framework (NEF). Our results show that it is possible to recreate the DFT spatial reasoning model using Nengo, since we were able to duplicate both the behavior of single neural fields and the whole model. However, there are statistical differences in performance between the two implementations, and future work is needed to determine the cause of these differences.

The Cognitive Modeling of Errors During the Japanese Phonological Awareness Formation Process

PO

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Shizuoka University, Japan

Both nature and nurture contribute to language development. In the case of phoneme segmentation, children have the natural ability to recognize a continuous sound in various units, but as they grow, they only selectively learn to recognize it as part of a series in the unit that is used in their mother tongue. This developmental process is supported by an ability called phonological awareness that allows children to become intentionally aware of units of phonology. It is known that erroneous pronunciation appears during the phonological awareness formation process. In this research, we aim to examine the factors that induce and reduce such errors. To do so, we modeled phonological awareness using the cognitive architecture ACT-R and performed simulations that manipulated ACT-R parameters that correspond to

both nature and nurture factors. As a result, it was confirmed that errors due to a lack of phonological awareness can be modeled with the innate memory retrieval mechanism. We also observed that such errors were reduced when learning factors were added to the model. However, we could not simulate this learning process. In the future, we will study the interaction task that enables learning to reduce phonological errors and contribute to the acquisition of phonological awareness.

Interactive Model-based Reminiscence using a Cognitive Model and Physiological Indices

PO

Itabashi, Kazuki (1); Morita, Junya (1); Hirayama, Takatsugu (2); Mase, Kenji (2); Yamada, Kazunori (3)

1: Shizuoka University, Japan; 2: Nagoya University, Japan; 3: Panasonic Corporation, Japan

In this study, we developed a photo slideshow system to support reminiscence activity. Compared to a conventional photo slideshow, the developed system has two features: incorporating a memory model based on the cognitive architecture ACT-R and modulation of the model parameter from the user's feedback. We assume that the first feature enables various patterns of photo presentation by the system, and the second feature makes the system adaptive to the user's response. More importantly, such presentation patterns and feedback can be theoretically designed by using cognitive architecture.In this paper, a preliminary evaluation of the developed system is presented. Through an analysis of the subjective evaluation of the system and changes in mental states, we clarified the effect of model-based reminiscence.In addition, heart rate variability (HRV) analysis was conducted to clarify the changes in the behavior of the model by feedback.

Establishing a paradigm to investigate strategy use in complex skills

PO

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Carnegie Mellon University, United States of America

Questions of strategy selection have been studied in various contexts such as problem solving, text editing, and even dynamic, fast-paced tasks. One way to model the strategy selection process is as a learning and decision problem: with experience, the agent learns the expected utilities of strategies, and executes a strategy based on what it has learned. However, the strategies studied in most of the past research have relatively stable utilities. Even when the task structure is manipulated to change the utilities of strategies, these changes are relatively infrequent. This contrasts with many real-world skills, such as sports and video gaming, where different strategies are optimal at different points during the learner's trajectory. As a learner practices a skill, improvements in the learner's degree of perceptual-motor calibration to the physics of tools and devices interacts with the difficulty of executing a strategy to affect the strategy's utility. Furthermore, it is often unknown what the maximum utility of any strategy will be, as this is partly determined by the learner's own general perceptual-motor abilities and prior experiences. How

humans learn and select strategies in the face of such variation and uncertainty behooves further investigation. Towards that goal, we present a task and strategy paradigm that captures many of the features of a typical complex skill. We also demonstrate possible interactions between strategy use, perceptual-motor calibration, and task knowledge using past experimental data and model simulations within the Adaptive Control of Thought-Rational (ACT-R) cognitive architecture.

Using cross-validation to determine dimensionality in multidimensional scaling

PO

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Multidimensional scaling (MDS) is a popular technique for embedding items in a low-dimensional spatial representation from a matrix of the dissimilarities among items (Shepard, 1962). MDS has been used simply as a visualization aid or dimensionality reduction technique in statistics and machine learning applications, but in cognitive science, MDS has also been interpreted as a cognitive model of similarity perception or similarity judgment, and is often part of a larger framework for modeling complex behaviors like categorization (Nosofsky, 1992) or generalization (Shepard, 2004). However, a persistent challenge in application of MDS is selecting the latent dimensionality of the inferred spatial representation; the dimensionality is a hyperparameter that the modeler must specify when fitting MDS.

Degenerate Optimal Boundaries for Multiple-Alternative Decision Making

PO

Baker, Sophie-Anne; Griffith, Thom; Lepora, Nathan

University of Bristol, United Kingdom

Integration-to-threshold models of two-choice perceptual decision making have guided our understanding of the behaviour and neural processing of humans and animals for decades. Although such models seem to extend naturally to multiple-choice decision making, consensus on a normative framework has yet to emerge, and hence the implications of threshold characteristics for multiple choices have only been partially explored. Here we consider sequential Bayesian inference as the basis for a normative framework together with a conceptualisation of decision making as a particle diffusing in n-dimensions. This framework implies highly choice-interdependent decision thresholds, where boundaries are a function of all choice-beliefs. We show that in general the optimal decision boundaries comprise a degenerate set of complex structures and speed-accuracy trade-offs, contrary to current 2-choice results. Such boundaries support both stationary and collapsing thresholds as optimal strategies for decision-making, both of which result from stationary complex boundary representations. This casts new light on the interpretation of urgency signals reported in neural recordings of decision making tasks, implying that they may originate from a more complex decision rule, and that the

signal as a distinct phenomenon may be misleading as to the true mechanism. Our findings point towards a much-needed normative theory of multiple-choice decision making, provide a characterisation of optimal decision thresholds under this framework, and inform the debate between stationary and dynamic decision boundaries for optimal decision making.

Decision making as a closed-loop process

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PO

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The theory of decision making has largely been developed as a disembodied open-loop process, however there is growing recognition that ecologically valid scenarios require integration of movement dynamics into current decision making theory, and a revision of what are considered to be core/fundamental decision components. Here we develop the theory of decision making as a closed loop process, first exploring the role of confidence both as a neural computation within the loop, affecting movement dynamics and as a property of the egocentric frame with a causal influence on cognition. Secondly, we consider the relationship between closed-loop components/processing and stability — in embodied systems action is accumulated and so physical restrictions limit volatility, moreover the reciprocal relationship between movement and evidence processing means that this stabilisation may also happen on a neural level in the form of a biased gain during evidence accumulation, improving stability/convergence. Finally, we examine closed-loop embodied decision making in the context of optimality — it is generally accepted that open-loop decision making is optimised to maximise reward via some form of Bayes' Risk, prescribing a speed-accuracy trade-off in so doing. For closed-loop decision making however, the form of the 'objective function' is unknown, as such we consider higher level, ecologically inspired ideas of optimality such as adaptability to e.g. moving targets or nonstationarity, to explore this fundamental aspect of embodied decision making.

Decoding the Mental States of Focus and Distraction in a Real Life Setting of Tibetan Monastic Debates Using EEG and Machine Learning

PO

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1: University of Groningen, The Netherlands; 2: Indian Institute of Technology, Roorkee, India

Cognitive science has started to make more and more use of techniques from machine learning to disentangle the neural correlates of cognitive processes. It can be particularly useful for complex situations in which many things are happening at the same time. Here we apply machine learning to investigate the cognitive processes in a rather novel situation: Tibetan monastic debate. Monastic debate is a core practice used in Tibetan monasteries to train preciseness of reasoning and

memorization. In the work presented here we distinguish between the occurrence of attentional states, focus and distraction. This gives insight into the cognitive effect of debate training.

An Expanded Set of Declarative Memory Functionalities in PyACTUp, a Python Implementation of ACT-UP's Accountable Modeling

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PO

1: University of Washington Seattle, United States of America; 2: Carnegie Mellon University, United States of America; 3: University of Virginia, United States of America

ACT-R, a well-established cognitive modeling architecture (Anderson, 2007) has been widely used in the field of cognitive psychology and neuroscience to interpret human cognition, memory formation and learning process. However, the programming difficulties in designing a model slows down the progress of cognitive modeling study. Inspired by Reitter and Lebiere (2010)'s ACT-UP, which is a subset of ACT-R declarative memory implementation, we introduce the Python implementation, PyACTUp, and expand its functionality to incorporate more important features from ACT-R. Current version of PyACT-UP provides great flexibility for modelers to define their own methods and meanwhile remains a simplified structure which is friendly to novice programmers.

Modelling Human Information Processing Limitations in Learning Tasks with Reinforcement Learning

Malloy, Tyler James; Sims, Chris R.

PO

Rensselaer Polytechnic Institute, New York, USA

In behavioral economics, 'rational inattention' (C. A. Sims, 2010) has been proposed as a theory of human decision-making subject to information processing limitations. This theory hypothesizes that decision-makers act so as to optimize a trade-off between the utility of their behavior, and the information processing effort required to reach a good decision. Shannon information has been proposed as a means of quantifying this information processing cost. However, existing models in the rational inattention framework do not account for the learning dynamics that underlie human decision-making. In order to incorporate the impact of cognitive limitations on learning, we extend the traditional reinforcement learning objective to incorporate a bound on the Shannon information of the learned policy (see also Lerch & Sims, 2019). Using experimental data from a previously-studied learning paradigm (Niv et al., 2015). we show that our method can be used to represent differences in participants' performance as resulting in part from utilizing different capacities for storing and processing information.

The following abstracts were submitted to MathPsych/ICCM 2020, and were peer reviewed and accepted, but had to be withdrawn from the conference due to the unusual circumstances of 2020.

A unified model of reward-learning and contextual decision-making in the basal ganglia

Griffith, Thom; Baker, Sophie-Anne; Lepora, Nathan

University of Bristol, United Kingdom

The problem of selecting actions from multiple alternatives has received considerable research attention. Studies show that normative models can implement the optimal policy for general multi-alternative decisions by accumulating choice evidence to non-linear, time-dependent thresholds. So far, however, such approaches have not accounted for tasks with context-dependent reward structures. Altering these reward structures gives rise to different speed-accuracy trade-offs and hence distinct optimal policies for different contexts. Here, we look to incorporate context-sensitivity into an accumulation-to-threshold model of decision-making, by introducing a reinforcement learning (RL) agent that learns context-sensitive, time-dependent thresholds. The threshold learning problem reveals itself as a contextual, multi-dimensional, continuous bandit problem for which we use the REINFORCE algorithm to update a parameterized policy with Gaussian sampling of thresholds. Within-trial threshold variation arises from context-sensitive dopaminergic modulation of D1 and D2 medium spiny neuron (MSN) activity in striatum. These MSNs signal the relative rewards and costs of individual actions; hence, their role in the model is to shift the decision threshold magnitudes in positive or negative directions, thereby increasing or decreasing the likelihood of selecting those actions. The model gives a plausible map of model parameters and variables to observations in the basal ganglia and cortex. In summary, our proposal unifies the modelling frameworks for reinforcement learning and decision-making in the basal ganglia, and furthermore provides a mechanism for learning associations between contextual cues and optimal speed-accuracy trade-offs.

Cognitive Models of Optimal Sequential Search

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Many everyday decisions require sequential search, according to which available choice options are observed one at a time, with each observation involving some cost to the decision maker. Decision makers have to choose the most desirable option out of the entire set of available options, without incurring excessive search costs. Optimal search in such tasks involves threshold decision rules, which terminate the

search as soon as an option exceeding a fixed reward value is found. Such rules can be seen as special cases of well-known algorithmic decision processes, such as the satisficing heuristic. Prior work has found that decision makers do use threshold rules, however the stopping thresholds observed in data are typically smaller than the (expected value maximizing) optimal threshold. We put forward an array of cognitive models and use parametric model fits on participant-level search data to examine why decision makers adopt seemingly suboptimal thresholds. We find that people's behavior is consistent with optimal search if we allow participants to display risk aversion, psychological effort cost, and (unsystematic) decision error. Thus, decision makers appear to be able to search in a resource-rational manner that maximizes stochastic risk averse utility. Our findings shed light on the psychological factors that guide sequential decision making, and show how threshold models can be used to describe both computational and algorithmic aspects of search behavior.

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