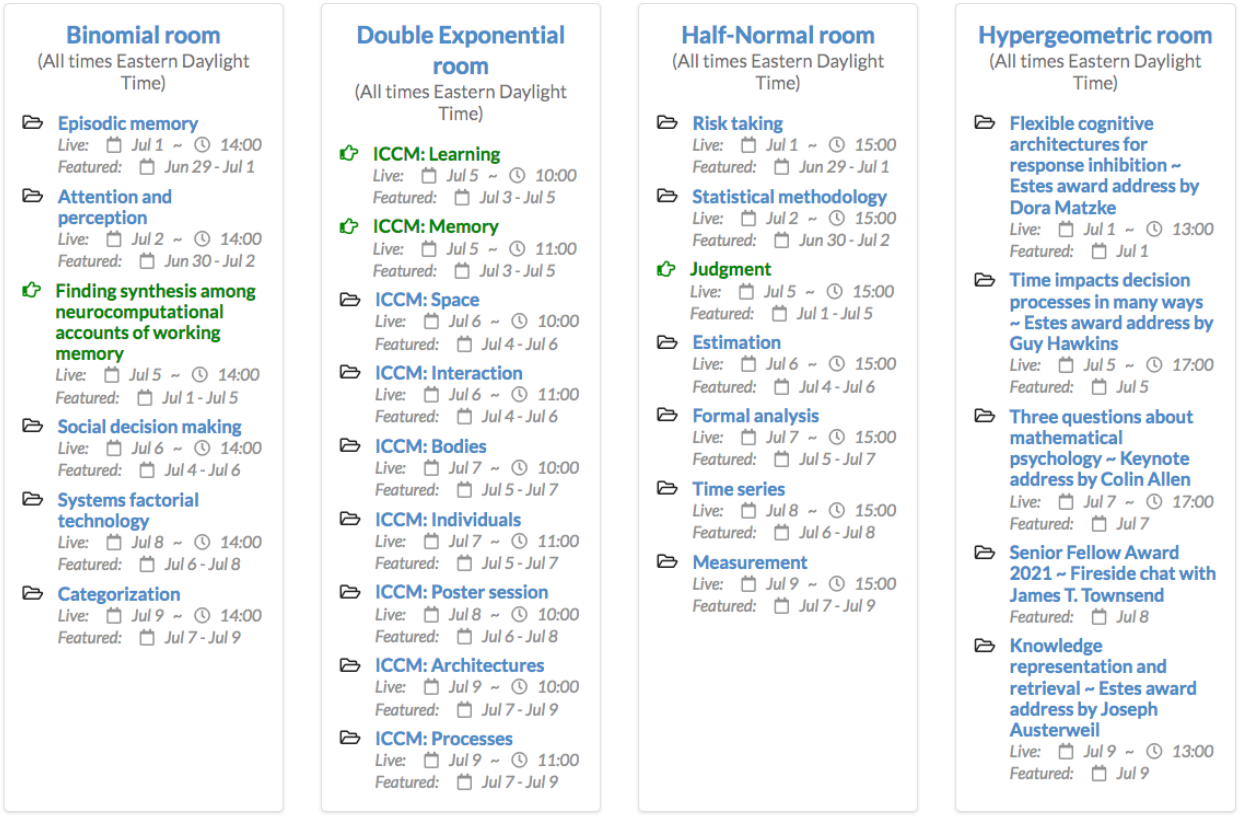
**MathPsych/ICCM 2021 Abstracts as a single booklet**
Conference Website: https://mathpsych.org/conference/7/schedule

**If you wish to read the abstracts and paper titles as a single document.**
Lizzy Meschia (enm5233@psu.edu) and Frank Ritter
4jul21

## Program

(in the web site, current activities are highlighted in green, thus you can see when I took the screenshot).



**Binomial room**
(All times Eastern Daylight Time)

- Episodic memory — Live: Jul 1 ~ 14:00 — Featured: Jun 29 - Jul 1
- Attention and perception — Live: Jul 2 ~ 14:00 — Featured: Jun 30 - Jul 2
- Finding synthesis among neurocomputational accounts of working memory — Live: Jul 5 ~ 14:00 — Featured: Jul 1 - Jul 5
- Social decision making — Live: Jul 6 ~ 14:00 — Featured: Jul 4 - Jul 6
- Systems factorial technology — Live: Jul 8 ~ 14:00 — Featured: Jul 6 - Jul 8
- Categorization — Live: Jul 9 ~ 14:00 — Featured: Jul 7 - Jul 9

**Double Exponential room**
(All times Eastern Daylight Time)

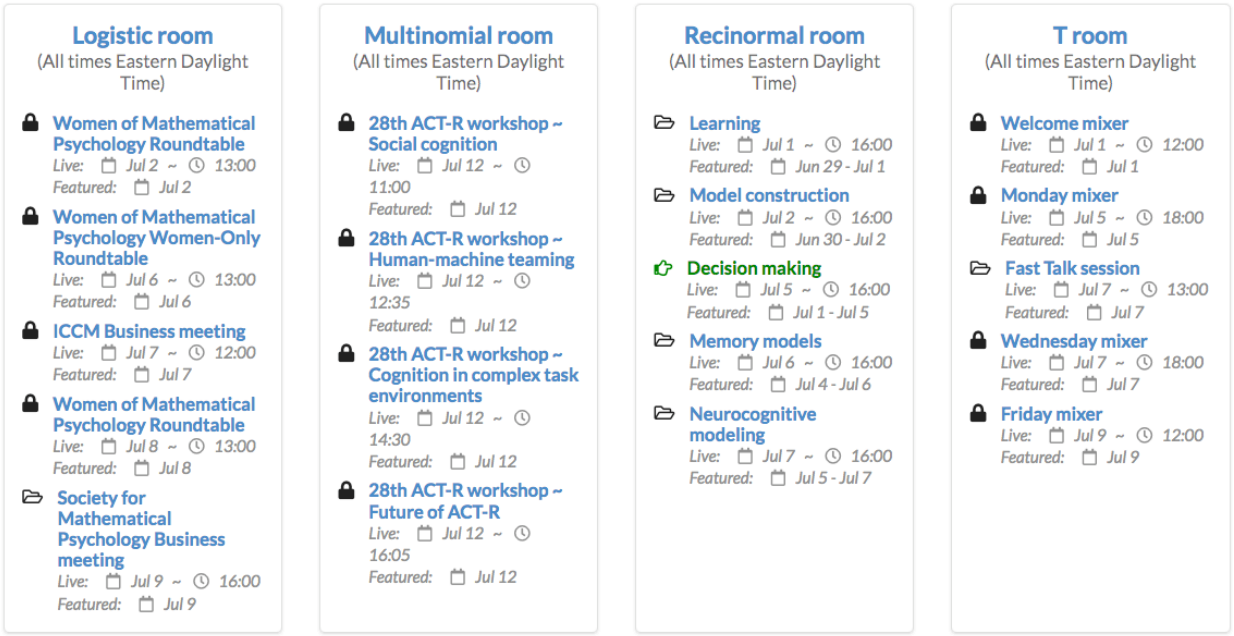
- ICCM: Learning — Live: Jul 5 ~ 10:00 — Featured: Jul 3 - Jul 5
- ICCM: Memory — Live: Jul 5 ~ 11:00 — Featured: Jul 3 - Jul 5
- ICCM: Space — Live: Jul 6 ~ 10:00 — Featured: Jul 4 - Jul 6
- ICCM: Interaction — Live: Jul 6 ~ 11:00 — Featured: Jul 4 - Jul 6
- ICCM: Bodies — Live: Jul 7 ~ 10:00 — Featured: Jul 5 - Jul 7
- ICCM: Individuals — Live: Jul 7 ~ 11:00 — Featured: Jul 5 - Jul 7
- ICCM: Poster session — Live: Jul 8 ~ 10:00 — Featured: Jul 6 - Jul 8
- ICCM: Architectures — Live: Jul 9 ~ 10:00 — Featured: Jul 7 - Jul 9
- ICCM: Processes — Live: Jul 9 ~ 11:00 — Featured: Jul 7 - Jul 9

**Half-Normal room**
(All times Eastern Daylight Time)

- Risk taking — Live: Jul 1 ~ 15:00 — Featured: Jun 29 - Jul 1
- Statistical methodology — Live: Jul 2 ~ 15:00 — Featured: Jun 30 - Jul 2
- Judgment — Live: Jul 5 ~ 15:00 — Featured: Jul 1 - Jul 5
- Estimation — Live: Jul 6 ~ 15:00 — Featured: Jul 4 - Jul 6
- Formal analysis — Live: Jul 7 ~ 15:00 — Featured: Jul 5 - Jul 7
- Time series — Live: Jul 8 ~ 15:00 — Featured: Jul 6 - Jul 8
- Measurement — Live: Jul 9 ~ 15:00 — Featured: Jul 7 - Jul 9

**Hypergeometric room**
(All times Eastern Daylight Time)

- Flexible cognitive architectures for response inhibition ~ Estes award address by Dora Matzke — Live: Jul 1 ~ 13:00 — Featured: Jul 1
- Time impacts decision processes in many ways ~ Estes award address by Guy Hawkins — Live: Jul 5 ~ 17:00 — Featured: Jul 5
- Three questions about mathematical psychology ~ Keynote address by Colin Allen — Live: Jul 7 ~ 17:00 — Featured: Jul 7
- Senior Fellow Award 2021 ~ Fireside chat with James T. Townsend — Featured: Jul 8
- Knowledge representation and retrieval ~ Estes award address by Joseph Austerweil — Live: Jul 9 ~ 13:00 — Featured: Jul 9




**Binomial room**

Episodic memory

- Dynamics of counterfactual retrieval
  - Authors:
    - Feiyi Wang (Presenting author)
    - Ada Aka (author)
    - Dr. Sudeep Bhatia (author)
  - Abstract: People often think about counterfactual possibilities to an event and imagine how it could have been otherwise. The study of how this occurs is central to many areas of cognitive psychology, including decision making, social cognition, and causal judgment; however, cognitive models of the memory processes at play during the generation of counterfactual thoughts have not yet been developed. Inspired by theories of list recall and semantic memory search, we build a formal model that examines how a sequence of counterfactual thoughts is retrieved from a set of all possible counterfactuals. Our approach takes the form of a Markov random walk over items in memory and allows for the activation of a counterfactual item to depend on its desirability, probability of selection, language frequency, and semantic similarity with the previously retrieved item. In this way, our model parametrically instantiates prior theories of counterfactual generation within a statistical model that can be fit to data from counterfactual generation tasks. Across three experiments, we show that our model describes and predicts the sequence of counterfactual thoughts that come to mind in response to a particular event, as well as the effects of these counterfactuals on subsequent evaluations and decisions. Our model can also explain key qualitative patterns in counterfactual generation and model the effects of contextual variables such as priming. Overall, our work shows how existing theories of counterfactual generation can be combined with quantitative models of memory

search to provide new insights about the generation and consequences of counterfactual thinking.

- A model-based analysis changes in the semantic structure of free recall due to cognitive impairment
    - Authors:
        - Holly Westfall (Presenting author)
        - Michael Lee (author)
    - Abstract: Alzheimer's disease leads to a decline in both episodic and semantic memory. Free recall tasks are commonly used in assessments designed to diagnose and monitor cognitive impairment, but tend to focus on episodic memory. Our goal is to understand the influence of semantic memory on the sequence of free recall in a clinical data set. We develop a cognitive process model that allows for the influence of semantic similarity and other stimulus properties on the order of free recall. The model also incorporates a decision process based on the Luce choice rule, allowing for different levels of response determinism. We apply the model to a real-world data set including free recall data from 2392 Alzheimer's patients and their caregivers. We find that semantic similarity between items strongly influences the order of free recall, regardless of impairment. We also observe a trend for response determinism to decrease as impairment increases.
- Investigating memory reactivation in news networks: Measure and compare exact and generative replay
    - Authors:
        - Dr. Yihe Lu (Presenting author)
    - Abstract: Memory reactivation can be observed during sleep or wakefulness in human and rodent brains, and is believed to be crucial for memory consolidation (Lewis and Bendor, 2019). A similar strategy, namely rehearsal or replay, is proven to be effective in mitigating, or even overcoming the catastrophic forgetting problem in neural network (NN) modelling and applications (Robins, 1995; Kumaran and McClelland, 2012). Generative replay (GR) (van de Ven, Siegelmann and Tolias, 2020) and experience replay (ER) (Káli and Dayan, 2004) are the two common replay strategies. While GR produces replay samples from random activations in a generative NN, ER revisits exact copies of past training samples preserved in memory storage. Although ER (without memory limits) yields better results and is thus deployed more in applications (e.g., machine learning), GR is computationally more efficient and biologically more plausible. In this study we chose restricted Boltzmann machines (RBMs) as our primary NN model. In addition to ER and GR, we consider a new strategy cued generative replay (cGR), which uses replay cues that are partially correct activations rather than completely random activations in standard GR. We propose two indices, evenness and exactness to measure the quality of replay samples. GR, in contrast to ER, yielded more balanced but less accurate replay (high evenness, low exactness), but their performance was largely dependent on the replay amount. We found that cGR could outperform both by improving replay quality
- A dynamic approach offers a unified account of recency and primacy in recognition memory: Integrating associative encoding and temporal context

- Authors:
  - Dr. Greg Cox (Presenting author)
- Abstract: Recognition memory for short lists shows effects of recency and primacy, which are typically explained using different mechanisms. I propose a single account that jointly explains recency and primacy. This account uses the same mechanisms that explain the dynamics of encoding and recognition of associations between items (Cox & Criss, 2020). When two items are presented simultaneously, separate representations of those items are gradually built by sampling perceptual and semantic features (Cox & Shiffrin, 2017). As this is happening, associative features are formed by making conjunctions between item features, and these associative features then end up shared between the originally separate item representations. I propose that this same process operates when items are presented in sequence, except that instead of forming associative features between two items, associative features conjoin features of a single item with those of its temporal context, which consists of features from preceding items (e.g., Howard & Kahana, 2002; Logan, 2020). This model accounts for recognition accuracy and response times across list lengths and serial positions (Nosofsky, Cox, Cao, & Shiffrin, 2014) as well as facilitation when study order is preserved at test (Schwartz et al., 2005). Recency and facilitation occur because the associative features between the test item and the prevailing temporal context are a strong match to the associative features formed at study. Primacy occurs because temporal contexts are stored in memory and they tend to over-represent early items. The same mechanisms that form associations between items within a trial can also explain associations between trials.

- A simulation model of sleep-dependent memory consolidation
  - Authors:
    - Dr. Yihe Lu (author)
    - Tamas Folde (Presenting author)
    - Prof. Penelope Lewis (author)
  - Abstract: Recent qualitative reviews show that sleep-dependent memory consolidation (SDMC) effects are highly task dependent. A growing body of research argues that encoding-related spontaneous reactivation and reactivation due to memory cueing during sleep play a causal role in SDMC, specifically for associative information and gist abstraction (Lewis, Knoblich & Poe, 2018). To better understand the relationship between task-dependency, reactivation, and rapid generalization a formal framework is necessary. We argue that an exemplar-based framework (Hintzman, 1986) is complementary to the existing connectionist computational models of reactivation (e.g: Kumaran & McClelland, 2012). By modelling offline reactivation as internally generated cued recall we can account for numerous behavioural SDMC findings (including episodic inference tasks, categorization, motor memory), some of which have been shown to be related to SWS. We discuss predictions regarding the effects of interference, memory strength, context and how they relate to existing verbal theories of SDMC. We conclude that recurrent similarity-based generalization is an ideal algorithm for modelling consolidation of newly encoded memories.

<u>Attention and perception</u>

- Nonlinear probability weighting can reflect attentional biases in sequential sampling
    - Authors:
        - Dr. Veronika Zilker (Presenting author)
        - Thorsten Pachur
    - Abstract:
        - Nonlinear probability weighting allows cumulative prospect theory (CPT) to account for key phenomena in decision making under risk (e.g., certainty effect, fourfold pattern of risk attitudes). It describes the impact of risky outcomes on preferences in terms of a rank-dependent nonlinear transformation of their objective probabilities. The attentional Drift Diffusion Model (aDDM) formalizes the finding that attentional biases toward an option can shape preferences within a sequential sampling process. Here we link these two influential frameworks. We used the aDDM to simulate choices between two options while systematically varying the strength of attentional biases to either option. The resulting choices were modeled with CPT. Changes in preference due to attentional biases in the aDDM were reflected in highly systematic signatures in the parameters of CPT's weighting function (curvature, elevation). Based on these insights, we predicted and demonstrated—in a re-analysis of a large set of previously published empirical data—that attentional biases are also systematically linked to patterns in probability weighting empirically. These findings highlight that distortions in probability weighting can arise from simple option-specific attentional biases in information search, and suggest an alternative to common interpretations of weighting-function parameters in terms of probability sensitivity and optimism. They also point to novel, attention-based explanations for empirical phenomena associated with characteristic shapes of CPT's probability-weighting function (e.g., certainty effect, description–experience gap). The results advance the integration of two prominent computational frameworks for decision making.
- The quest for simplicity in human learning
    - Authors:
        - Mr. Matthew Galdo (Presenting author)
        - Vladimir Sloutsky
        - Dr. Brandon Turner
    - Abstract:
        - For better or worse, humans live a resource constrained existence; for example, only a fraction of the sensations our body experiences ever reach conscious awareness, and we store a shockingly small subset of these experiences in short-term memory for later use. Despite these observations, most theories of learning assume that, given feedback about a new experience, our representations are updated so as to minimize subsequent errors with minimal consideration of cognitive capacity constraints. Acknowledging that human cognition has clear biological limitations, we explored the degree to which human learning could be better described with sets of biases toward simpler and more parsimonious mental representations

(i.e., simplicity biases) relative to an error-driven, accuracy-maximizing normative model. Taking the normative model as a basis, we developed a suite of computational models that use various mechanistic simplicity biases to explain learning. We fit these models to four data sets that varied in the type of learning needed to achieve high accuracy. Across all data sets, we found consistent evidence that the best descriptors of human learning were models with mechanisms that instantiated a constrained optimization process, where errors were minimized subject to constraints on both attention and memory. Importantly, whereas normative models failed to account for patterns of attentional deployment over time, models with simplicity biases accounted well for both choice responses and gaze fixation data as participants learned various tasks.

- Using observer models to formalize the mechanisms underlying face perception biases in depression
    - Authors:
        - Fabian Soto (Presenting author)
        - Mr. Jason Hays
        - Dr. Christopher Beevers
    - Abstract:
        - Here, we take a computational approach to understand the mechanisms underlying face perception biases in depression. Participants diagnosed with Major Depressive Disorder (MDD, N=30) and healthy controls (N=30) took part in a study involving recognition of identity and emotion in faces. We used signal detection theory (SDT) to determine whether any perceptual biases exist in depression aside from decisional biases. We found lower sensitivity to happiness in general, and lower sensitivity to both happiness and sadness with ambiguous stimuli. We found no systematic effect of depression on the perceptual interactions between face expression and identity, suggesting that depression is not associated with difficulty selectively attending to one of these dimensions. Our use of SDT allows us to link these psychophysical results to an neurocomputational model of the encoding of facial expression. We show through simulation that the overall pattern of results, as well as other biases found in the literature, can be explained by selective suppression of neural populations encoding positive expressions in MDD. In a second study, we used reverse correlation to show that one source of this suppression could be a difference between participants diagnosed with MDD and healthy controls in the information sampled in order to detect happiness and sadness in faces. We show that the psychophysical observer models obtained through reverse correlation offer a complementary way to account for the results of our first study. Our model-based approach is a step forward toward understanding the mechanisms underlying face perception biases in psychiatric disorders.
- Interactive attention to amount and time information in intertemporal choice
    - Authors:
        - Dr. Lisheng He (Presenting author)

        - Dr. Sudeep Bhatia
    - Abstract:
        - The study of attention dynamics in decision making has been increasingly important in uncovering the cognitive principles of choice behavior, including intertemporal choice. Recently, empirical work on this topic has suggested that the two attributes involved in intertemporal choice (monetary amounts and time delays) have distinct and independent influences on the choice process, and that these attributes are additively aggregated in an evidence accumulation process. In this paper we outline theoretical problems with such an account, and argue that intertemporal choice processes necessarily includes interaction between the two attributes in order to generate reasonable choice behavior. Furthermore, we re-examine existing eye-tracking datasets of intertemporal choice using a Markov model of attentional dynamics. Our model assumes that the transitions between distinct attentional states (e.g. amounts and delays of the two options) depend on a large number of variables, including, crucially, the most recently attended attribute value. We estimate model parameters within a hierarchical Bayesian framework and find that high values of currently sampled information lead to more frequent transitions to the other attribute within the same option. Thus, for example, participants are more likely to sample the time delay of an option when the monetary amount is high, relative to when the amount is low (and vice versa). This corresponds to interdependent and interactive attention dynamics during decision making. We conclude by examining how such an interactive attentional process can combine with an attention-based evidence accumulation process to generate observed patterns in intertemporal choice behavior.
- The influence of the place value system on symbolic number perception in a ruler task
    - Authors:
        - Yvonne Oberholzer (Presenting author)
        - Marcus Lindskog
        - Benjamin Scheibehenne
    - Abstract:
        - Research on numerical cognition has suggested that there is compression in both, symbolic (e.g., Arabic numerals) and non-symbolic (e.g., dot clouds) number perception. More specifically, symbolic and non-symbolic numbers are supposed to be mapped onto the same compressed mental analogue representation. However, experiments using magnitude estimation tasks show logarithmic compression of symbolic numbers while the compression of non-symbolic numbers has a power-function shape. This warrants closer inspection at what differentiates the two processes. In this study, we hypothesized that estimates of symbolic numbers are systematically shaped by the format in which they are represented, namely the place value system. To investigate this, we tested adults (n = 188) on a repeated magnitude estimation task with unfamiliar base-26 and base-5 scales and fitted a hierarchical logarithmic, a hierarchical power and a hierarchical linear model

to the data. Results revealed that adults showed systematic, logarithmic-looking underestimation on both scales, indicating that the place value system itself can cause the pattern. Additionally, the observed shape of participants' estimates on both scales could be well-explained with a simple model that assumed insufficient understanding of exponential growth (i.e., a characteristic of place value systems). Taken together, our results suggest that the discrepancy between symbolic and non-symbolic number compression can be explained by taking the effect of the place-value system into account.

- Dynamic criteria in duration discrimination tasks: An alternative to the scalar property of time perception?
    - Authors:
        - Berenice López-Casal (Presenting author)
        - Rocio Alcala-Quintana
    - Abstract:
        - Our ability to discriminate short durations can be studied through Signal-Detection-Theory based models. They incorporate the sensory, decision, and response mechanisms that govern observers' responses in duration discrimination tasks, and serve as a guide to test substantive hypotheses about each of these components. The standard version of these models states that the sensory mechanism relies solely on the magnitude of the difference in duration of the stimuli to be compared. This is incompatible with some empirical results, which have shown that psychometric functions change with the duration of the reference stimulus. These results have been attributed to some form of the scalar property of time perception, but they could also be produced by shifts in decisional criteria. Here we present a series of four models that incorporate the scalar property, decisional criteria that vary with stimulus duration, or both, along with the standard model. We show that each model gives rise to psychometric functions with distinct characteristics, which raises the question of whether these models are also distinguishable in practice. We tackle this question through a simulation study whose results show that parameters can be adequately recovered, and that the data-generating model can be correctly selected using goodness-of-fit procedures. This framework provides a solid ground to design experiments that allow testing how sensory and decisional mechanisms contribute to judgements in duration discrimination tasks.

Finding synthesis among nerocomputaila accounts of working memory

- An interference model of visual working memory: serial-position effects
    - Authors:
        - Klaus Oberauer (Presenting author)
    - Abstract: We will present work that starts to build a bridge between formal models of visual working memory for simultaneously presented arrays on the one hand, and models for explaining recall of sequentially presented lists on the other. We start from our Interference Model (Oberauer & Lin, 2017) and extend it to the recall of sequentially presented lists of visual objects. The model builds on the assumption

that access to items in working memory relies on cue-based retrieval, which engenders interference as a main source of performance limitation. To account for serial-position effects, we add two new assumptions: With each new item working memory is updated by automatically down-grading previous contents. To counteract this process, encoding of early list items receives an attentional boost, which declines for successive items, creating a primacy gradient. We present a Bayesian hierarchical version of the model, and fits to data of a continuous-reproduction visual-working memory experiment in which up to six items were presented sequentially, and tested in a random order. The model accounts for the distributions of errors, the set-size effect, and serial-position effects over input and output positions.

- A flexible model of working memory
    - Authors:
        - Flora Bouchacourt (Presenting author)
        - Tim Buschman
    - Abstract: Working memory is fundamental to cognition, allowing one to hold information “in mind.” A defining characteristic of working memory is its flexibility: we can hold anything in mind. However, typical models of working memory rely on finely tuned, content-specific attractors to persistently maintain neural activity and therefore do not allow for the flexibility observed in behavior. Here, we present a flexible model of working memory that maintains representations through random recurrent connections between two layers of neurons: a structured “sensory” layer and a randomly connected, unstructured layer. As the interactions are untuned with respect to the content being stored, the network maintains any arbitrary input. However, in our model, this flexibility comes at a cost: the random connections overlap, leading to interference between representations and limiting the memory capacity of the network. Additionally, our model captures several other key behavioral and neurophysiological characteristics of working memory.
- Stochastic sampling provides a unifying perspective on working memory limits
    - Authors:
        - Dr. Paul Bays (Presenting author)
    - Abstract: Recent debate regarding the limits of working memory has focused on whether memory resources are better characterized as discrete or continuous, with models of each type competing to best capture the errors humans make in recall. I will argue that this apparent dichotomy is largely illusory, and that the critical distinction is instead between deterministic and stochastic mechanisms of WM, with only the latter being compatible with observed human performance and the underlying biological system. I will show that reconceptualizing existing models in terms of sampling reveals strong commonalities between supposedly opposing accounts. A probabilistic limit on how many items can be successfully recalled from WM is an emergent property of continuous models, despite these models having no explicit mechanism to enforce such a limit. Furthermore, adding stochasticity in the number of samples to a discrete model puts its ability to describe behaviour on a par with continuous models. Finally, stochastic sampling has a theoretical connection with biologically plausible implementations of WM based on the inherently stochastic activity of neural populations.

- Memory for latent representations
    - Authors:
        - Prof. Brad Wyble
        - Mr. Ryan O'Donnell
        - Shekoofeh Hedayati (Presenting author)
    - Abstract: Early theories of working memory (WM) (Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Baddeley, 2000, Ericsson & Kintsch,1995) have discussed the essential role of visual knowledge and long-term memory in WM performance. Yet, there is no computational model to show how WM representations can be built from the visual knowledge using neurocomputational mechanisms. We propose a model of WM-visual knowledge that uses the latent representations in a visual knowledge network to encode information in memory. This neurally plausible model (named MLR) represents visual knowledge using a variational autoencoder (VAE; Kingma & Welling, 2013) that learns to compress and reconstruct the pixle-wise visual stimuli. We modified the VAE to represent shape and color in separate maps, to be able to test theories of shape-color bindings. The MLR model uses a binding pool (BP; Swan & Wyble, 2014) to flexibly store information in a shared neural resource, such that attributes of an item (e.g., shape and color) could be represented in one memory system, and bound together according to task demands. The storage of information in working memory is accomplished through self-sustaining activity patterns, and synaptic weights are fixed during storage and retrieval. We showed that MLR can efficiently store and retrieve familiar items when their compressed representation in visual knowledge is encoded. On the other hand, novel items could be encoded and retrieved from less compressed representations. Additionally, the MLR model could extract the categorical information of an item and store it in memory along with the visual information. Finally, our model provides an explanation of how WM is linked to visual knowledge, to store familiar stimuli efficiently, while also being able to build on-the-fly memories of novel stimuli.
- Attractors for action selection in working memory
    - Authors:
        - Prof. Sanjay Manohar (Presenting author)
    - Abstract: A central feature of WM is its ablility to not only store information, but also utilise it. Most models of WM don't specify how information is read out and used. This shifts the burden to other systems. But recent work suggests that WM is task dependent, dynamic, and itself involves manipulation. We propose that WM representations should themselves be able to make decisions and select actions. WM should be effectual. Accordingly, one recent perspective suggests that WM holds a set of rules for transforming stimuli to responses. For example in change detection tasks, WM may function as a "matched filter", and in graded judgements, as a decision-making circuit. Can we model this? We propose that this functionality corresponds to the ability to set up multiple new attractor states. We show that a minimal array of Hebbian units can rapidly carve out an attractor that binds the features of an item. A matching input can trigger competition between these attractors, with the winner potentially triggering an action. The dynamics can "gate" items in and out of memory, but without needing a gatekeeper. We think of this as a

primitive but concrete implementation of a multiple demand network, holding pointers that bind features in sensory stores. Competition between plastic attractors replicates Hick's law of decisions, trial history effects, and some conflict effects previously explained by "event files". We were also able to apply plastic attractors to a simple situation where WM gets put to immediate use: Visual search. The template that is being searched for is encoded into WM, and the search display acts as a memory probe, triggering attention to select the matching item. The model also extends to continuous feature domains, where it generates predictions similar to the interference model. We hope this work encourages a view where WM encodes information in terms of active effects or responses, making representations inherently potent.

Social decision making

- Towards a computational model of social meta-inference and the evidentiary value of consensus
    - Authors:
        - Keith Ransom
        - Andrew Perfors
        - Rachel Stephens
    - Abstract: Reasoning beyond available data is a ubiquitous feature of human cognition. But while the availability of first-hand data typically diminishes with increasing complexity of reasoning topics, people's ability to draw inferences seems not to. Reasoners may offset the sparsity of direct evidence with evidence that is inferred by observing the statements and actions of others. But this kind of social meta-inference comes with challenges of its own. In evaluating a claim about an unfamiliar topic, a reasoner might sensibly assume that a person who makes an argument in its favour is in possession of some evidence - but how much? How should the evaluation vary with the number of people arguing on each side? Should repeated arguments carry more weight than distinct ones? How people reason in this situation is likely to depend on their assumptions about the generative process behind communication. Here we present preliminary work towards a computational model of the kinds of inferences required when reasoning from indirect evidence, and we examine candidate model predictions via an experiment investigating the evidentiary strength of consensus in the context of social media posts. By systematically varying the degree of consensus along with the diversity of people and arguments involved we are able to assess the contribution of each factor to evidentiary weight. Across a range of topics where reasoning from first-hand data is more or less difficult we find that while people were influenced by the number of people on each side of an argument, the number of posts was the dominant factor in determining how people updated their beliefs. However, in contrast to well established premise diversity effects, our findings suggest that repeated arguments may carry more weight.
- Minds for mobile agents
    - Authors:
        - Prof. Andrew Heathcote
        - Charlotte Coosje Tanis
        - Mr. Jonne Zomerdijk

        - Dr. Tessa Blanken
        - Dr. Dora Matzke
        - Prof. Denny Borsboom
    - Abstract: We model large sets of interacting mobile agents whose movement choices are determined in a discrete-choice random-utility framework spanning simple multinomial logit models to crossed-nested logit models that account for velocity-related correlations. The agents are predictive, so their choice utility is in part based on projecting the future positions of other agents they observe. They can have diverse characteristics and individual movement plans consisting of goals about visiting sets of locations. When a plan is disrupted through interactions with other agents in crowded scenarios, they can dynamically create sub-goals to enable them to return to complete their mission. Additive combinations of choice utilities provide a method to combine, weight, and resolve sets competing demands from goals (e.g., heading to the next location), individual preferences (e.g., for speed and inter-personal distance), rules (e.g., passing on the right) and social factors (e.g., following a leader and grouping). We report simulations showing that these agents can competently navigate and achieve their goals in difficult environments and results on Bayesian estimation of agent parameters from movement data. We discuss the potential for this framework to build, parametrize, explore, and predict systems of agents guided by complex and flexibly specified cognitive states.
- Polarization and extremism emerge from rational choice: Estimation as a solution to biased sampling
    - Authors:
        - Abhay Alaukik
        - Peter Kvam
        - Matthew Baldwin
        - Callie Mims
        - Arina Martemyanova
    - Abstract: Polarization is often described as the product of biased information search, motivated reasoning, or other psychological biases. However, polarization and extremism can still occur in the absence of any bias or irrational thinking. In this talk, we show that polarization occurs among groups of decision makers who are implementing rational choice strategies (specifically, random walk / relative evidence choice strategies) that maximize decision efficiency. This occurs because extreme information enables decision makers to make up their minds and stop considering new information, whereas moderate information is unlikely to trigger a decision and is thus under-represented in the sampled information. Furthermore, groups of decision makers will generate extremists – individuals who stop sampling after examining extreme information. In re-analyses of seven empirical studies spanning perceptual and preferential choice, a series of simulations manipulating threshold, bias, and drift rates, and a new study examining politically and affectively charged decisions, we show that both polarization and extremism manifest when decision makers gather information to make a choice (choice task). Polarization did not occur, however, when participants made an inference about the difference between two quantities (estimation task). Estimation therefore offers a theoretically-motivated intervention

that can increase the amount of information people consider and reduce the degree of polarization and extremism among groups of individuals.

- Improving medical image decision making by leveraging representational similarity
    - Authors:
        - Eeshan Hasan
        - Jennifer Trueblood
        - Dr. Quintin Eichbaum
        - Dr. Adam Seegmiller
        - Dr. Charles Stratton
    - Abstract: Improving the accuracy of medical image interpretation is critical to improving the diagnosis of many diseases. Research in human decision-making has shown that a Wisdom of the Inner Crowd approach can improve the accuracy of individual decision-makers. In this approach, repeated judgments from the same decision maker on the same stimuli are aggregated. Since repeated decisions in medical contexts are time intensive and potentially costly, we test whether it is possible to aggregate decisions on not necessarily the same but similar images. In a series of experiments, we use the classification decisions (cancerous vs non-cancerous) collected with novice and expert participants on a set of white blood cell images. To determine the similarity between cell images, we use the latent representations of the images from neural network models. We investigate two different representations, distinguished by how the neural networks were trained. The first representation was obtained by training a neural network on the cancer classification task. The second representation was obtained by training the neural network on an unrelated task (i.e., categorizing natural images, but not cell images). We observe that these methods work better for novices than experts. This suggests that novices and experts have different decision mechanisms, where the novices make random errors while experts are systematically biased. Finally, using a better representation not only allows for larger improvements in accuracy but also allows for aggregation over more images.
- Task difficulty and task rule affect the group decision efficiency
    - Authors:
        - Peng-Fei Zhu
        - Hanshu Zhang
        - Cheng Ju Hsieh
        - Mario Fific
        - Prof. Cheng-Ta Yang
    - Abstract: Although most previous studies indicated that aggregating group-level decisions is superior to individual decisions, some studies argued that collaboration does not always result in better performance. It is still unclear how task context may influence the group decision advantage. To examine the effect of task rule and task difficulty on the collective decision-making process, we applied Systems Factorial Technology to measure group decision-making efficiency in three visual search experiments (i.e., a T/L conjunction search task): In both Experiments 1 and 3, participants had to report the number of the targets (i.e., AND search rule), and trials

including uncertain target numbers were used as catch trials in Experiment 3 to prevent early search termination; In Experiment 2, participants had to detect the presence of any target (i.e., OR search rule). The results revealed supercapacity processing under both task rules by comparing the group to individual subject's performance, suggesting a collective benefit. Most interestingly, the degree of how the collective benefit is affected by the task difficulty depends on the task rule. With an OR rule, collective benefit was unaffected by the number of distractors whereas with an AND rule, collective benefit increased as the task difficulty increased. To conclude, our research suggested that group decisions can outperform individual decisions by showing more efficient processing; and the efficiency effect is prominent with difficult tasks and exhaustive searching rule conditions, respectively.

System factorial technology

- The influence of dual-task load on redundant signal processes
    - Author
        - Betsy Fox
        - Dr. Zach Howard
        - Prof. Cheng-Ta Yang
        - Hao-Lun Fu
        - Dr. Kanthika Latthirun
        - Dr. Ashley Cook
    - Abstract: Current technology and workplace environments are designed to enable people to attempt multiple tasks simultaneously. Consequentially, people divide their limited attentional resources among many competing demands. In some recent work, Morey et al. (2018) found the limited processing capacity to redundant targets in a peripheral task did not change depending on the difficulty or presence of a dual-task. Nonetheless, it is unknown how 1) the introduction of, or increased difficulty of, a second task may change how people combine multiple peripheral targets (e.g., in parallel or serial) and 2) processing efficiency may depend on both the salience of peripheral targets and the presence/difficulty of a second task. In this work, we use systems factorial technology to investigate the cognitive processing mechanisms of redundant visual targets in isolation and in the context of an easy or difficult multiple object tracking (MOT) task. We manipulate the degree of MOT demands: track 0, 1, or 4 dots, and the salience of peripheral red target squares (easy, difficult). We find limited-capacity parallel-OR processing of redundant targets but the degree of limited processing capacity depends on the demands of the MOT (0, 1, or 4 dots) and the salience of the dual-targets (low/high). Our data suggest that the structure for how people process multiple peripheral cues does not change depending on the overall attentional demands of the task(s); however, the extent that people benefit from redundant information may depend on how difficult it is to perceive the targets and external task demands.
- Generalized assessment functions based on Grice representations
    - Author
        - Prof. Joe Houpt
        - Cara Kneeland

    - Abstract: Understanding how human performance changes as the amount of information available varies is of particular interest across many basic and applied research topics in psychology. One approach to quantifying these changes is with the assessment functions. Briefly, the assessment functions are a family of non-parametric measures that compare observed performance to a baseline derived from a model predicting how changes in information influence the system. Although less commonly used than the capacity coefficient, a similar measure based only on response-time data, the assessment functions are a promising tool because it accounts for response-time and accuracy, and hence is applicable in conditions in which speed-accuracy trade-offs can vary. Two potential hinderances to the wider use of the assessment functions are the specific assumptions needed to derive the baseline model and the lack of associated inferential statistics. In this talk, we demonstrate how a fixed accumulator model with a random threshold (i.e., Grice model) representation of the choice/RT data can be leveraged to derive generalized assessment functions and, potentially, for deriving inferential statistical tests.
- If Linda was a square grid: the conjunction fallacy in the psycho-physical domain
    - Author
        - Prince Kouassi
        - Dr. James Yearsley
        - Prof. Emmanuel Pothos
    - Abstract: Research on the conjunction fallacy has largely been concerned with exploring its underlying causes. Conventional methods primarily use descriptive scenario-based tasks to represent probabilities. However, such descriptive methods are prone to misinterpretation and other cognitive biases. We attempt to demonstrate how these problems can be overcome by applying a psycho-physical framework, which represents probabilities as proportions of blue-to-orange squares in a grid. Results show that a psycho-physical framework can demonstrate a conjunction fallacy. Preliminary evidence accumulation modelling shows that the conjunction fallacy appears to be driven by changes in information processing specifically and not by changes in speed-accuracy trade-offs. To further investigate the information processing involved in the conjunction fallacy, systems factorial technology was applied to the results. This was done by fitting a linear ballistic accumulator to the empirical results, then simulating experimental responses and response times based on the logic of systems factorial technology information processing architectures. Simulation results go on to show that because the inherent logic of the systems factorial technology architectures assume independent processing of information in the different channels, they cannot produce conjunction fallacies. However, allowing crosstalk between the architecture channels, either via a bias in the start point of evidence accumulation for serial architectures, or collapsing the response threshold after terminating evidence accumulation in one channel for parallel architectures, can lead to conjunction fallacies. Empirical and simulation results are argued to show that a bias in the start point of evidence accumulation for serial architectures is the most plausible cause of conjunction fallacies.
- Inter-relationship of categorization and decision in a two-stage paradigm
    - Author

        - Yanjun Liu
        - James T. Townsend
    - Abstract: Revolving around a two-stage decisional paradigm where a categorical decision was followed by an action decision, an inconsistency in choice behavior when both decisions were explicitly measured versus when only the second decision was measured has been revealed and replicated in the past twenty years. Such an inconsistency in choice behavior, referred as the interference effect, violates the fundamental properties of probability theory: the law of total probability and the Markov property and thus challenges a wide range of classical cognitive models of decision-making. Substantial theoretical efforts in the past decade have been devoted to interpreting the underlying cognitive mechanisms producing the interference effect. However, most of these efforts have relied on critical assumptions of the underlying cognitive structure and did not consider the response-time performance. To this end, the current study adapted the two-stage decisional paradigm for the extended application of a set of theory-driven response-time based measurements. Conjoining the utilization of the response-frequency measurement, we probe the underlying cognitive properties that may relate to the occurrence of interference effect. The results showed that with fewer restrictions on a sequential processing order of categorization and action decisions, the underlying cognitive systems tended to follow a parallel mental architecture and the processing speed of the deliberation processes tended to facilitate each other, along with observations of the interference effect in response frequencies. These results suggested that interference effects might be closely pertinent to cognitive systems characterized by parallel mental architecture and positively interact underlying deliberation processes of categorization and action decision.
- Aerobic fitness is associated with resilience capacity for faster decisions in young adults
    - Author
        - Hao-Lun Fu
        - Prof. Shih-Chun Kao
        - Chun-Hao Wang
        - Prof. Cheng-Ta Yang
    - Abstract: Previous studies have shown individuals with higher level of aerobic fitness exhibited better cognitive control. However, less is known about how aerobic fitness level relates to resilience capacity, a measure of the change in multi-signal processing efficiency in the presence of the distractors. Thus, the aim of the present study is to examine whether aerobic fitness is related to individual differences in resilience capacity.Twenty-two young adults with higher level of aerobic fitness (high-fit group; aged 21.05 ± 2.15 years; VO2max = 58.36 ± 6.71 ml/kg/min) and twenty-two demographically matched lower aerobic fitness counterparts (low-fit group; aged 22.23 ± 1.38 years; VO2max = 41.74 ± 4.03 ml/kg/min) performed a Go/Nogo version of the redundant-target detection task. According to Systems Factorial Technology (SFT), resilience capacity was assessed by comparing the processing efficiency when two targets were simultaneously presented to when a target and a distractor were presented. Further, a functional principal component analysis (fPCA) was applied for exploratory analysis of the resilience capacity. Results revealed no

group differences in mean reaction times (RTs) across task conditions. In terms of SFT, the fPCA results revealed larger resilience capacity in the high-fit group compared with the low-fit group for the faster responses, while such difference was not found for the slower responses. Novel to the current study is to provide a more comprehensive investigation of the cognitive benefits of aerobic fitness. In conclusion, the study suggests that the beneficial association of greater aerobic fitness with information processing efficiency may change dynamically across response times.

Categorization

- Learning new categories for natural objects
    - Authors:
        - Ms. Wanling Zou
        - Dr. Sudeep Bhatia
    - Abstract: People learn new categories on a daily basis, and the study of category learning is a major topic of research in cognitive science. However, most prior work has focused on how people learn categories over abstracted, artificial (and usually perceptual) representations. Little is known about how new categories are learnt for natural objects, for which people have extensive prior knowledge. We examine this question in three pre-registered studies involving the learning of new categories for everyday foods. Our models use word vectors derived from large-scale natural language data to proxy mental representations for foods, and apply classical models of categorization over these vectorized representations to predict participant categorization judgments. This approach achieves high predictive accuracy rates, and can be used to identify the real-world settings in which category learning is impaired. In doing so, it shows how existing theories of categorization can be used to predict and improve everyday cognition and behavior.
- The influence of learning context on response times: A reinforcement learning sequential sampling model analysis
    - Authors:
        - Dr. Laura Fontanesi
        - Jorg Rieskamp
    - Abstract: In previous work, we showed how different learning contexts affected not only choice proportion but also decision time: Participants tend to give faster responses in higher-value contexts compared to low-value contexts. To explain these effects, we combined traditional reinforcement learning models–which model across-trial dynamics–with sequential sampling models–which model within-trial dynamics. However, it remains to be assessed whether the magnitude and sign of rewards are associated with different decision mechanisms (i.e., decision caution or motor facilitation). In this study, we manipulated both the magnitude and sign of rewards in a within-participant design. We found that the two manipulations had overall different effects on the joint choice proportion and response times patterns. We propose a new model that attempts to explain such patterns and therefore provide a concise and comprehensive account of value effects on decision-making in reinforcement learning
- Recovering human category structure across development using sparse judgments

- Authors:
  - Pablo Leon Villagra
  - Christopher Lucas
  - Isaac Ehrlich
  - Daphna Buchsbaum
- Abstract: Multidimensional scaling (MDS) has provided insight into the structure of human perception and conceptual knowledge and has been central in the development of models of cognition. However, MDS usually requires participants to produce large numbers of similarity judgments, leading to long and repetitive experiments. Here we propose a method that combines a simple grouping task with a neural network model to uncover participants' psychological spaces. We validate the method on simulated data and find that it can recover the true global structure even when given heterogeneous groupings. We then apply the method to data from the World Color Survey and find that it can learn language-specific color organization. Finally, we apply the method to a novel developmental experiment and find age-dependent differences in conceptual spaces. Our results suggest that the method can be used to recover similarity judgments from populations for which traditional MDS setups would be prohibitively taxing, such as in developmental studies. These similarities, in turn, are crucial for the development of detailed models of category learning.

- Co-occurrence statistics can explain the development of early taxonomic links
  - Authors:
    - Dr. Hyungwook Yim
    - Dr. Olivera Savic
    - Ms. Alexandria Barkhimer
    - Dr. Vladimir Sloutsky
    - Prof. Simon Dennis
  - Abstract: Decades of cognitive development research focused on how and when human learners acquire taxonomic links - links that connect concepts belonging to the same semantic category, such as fruit, bird, or furniture. As learning taxonomic links requires the ability to detect key features shared by members of a semantic category, studies have shown that the formation of taxonomic links in semantic memory has a protracted development. However, recent studies report that taxonomic links may be formed even at the age of six months. The goal of the current study was to provide an explanation of the inconsistency across these studies. We examined the possibility that taxonomic links that are acquired early in life will also co-occur frequently, and, therefore, the seemingly taxonomic links early in life are actually driven by co-occurrence statistics. To test this assumption, we selected studies that claim early taxonomic development and studies that claim protracted taxonomic development. Then we calculated the co-occurrence statistics (i.e., cubed pointwise mutual information) between the word pairs using the TASA corpus. Results showed that the studies supporting an early taxonomic development used word pairs that have high co-occurrence statistics, while the studies supporting a late taxonomic development used word pairs that have low co-occurrence

statistics. Our results provide evidence that early in development, links between some taxonomically related concepts may stem from co-occurrence regularities.

- Comparing Markov and quantum random walk models of categorization decisions
    - Authors:
        - Mr. Gunnar Epping
        - Dr. Jerome Busemeyer
    - Abstract: Quantum probability theory has successfully provided accurate descriptions of behavior in the areas of judgment and decision making, and here we apply the same principles to two category learning tasks, one task using overlapping, information-integration (II) categories the other using overlapping, rule-based (RB) categories. Since II categories lack verbalizable descriptions, unlike RB categories, we assert that an II categorization decision is constructed out of an indefinite state and characterized by quantum probability theory, whereas an RB categorization decision is read out from a definite state and governed by classical probability theory. In our experiment, participants learn to categorize simple, visual stimuli as members of either category S or category K during an acquisition phase, and then rate the likelihood on a scale of 0 to 5 that a stimulus belongs to one category and subsequently perform the same likelihood rating for the other category during a transfer phase. Following the principle of complementarity in quantum theory, we expect the category likelihood ratings to exhibit order effects in the task that employs II categories, but not in the one that uses RB categories. In the task with II categories, we found that the quantum random walk model notably outperforms an analogous Markov random walk model and there are definitive order effects in the likelihood ratings. But in the task with RB categories, we found that the performance gap between the Markov and quantum models is reduced and the order effects in the likelihood ratings are not significant.
- The effect of economic incentives on the learning of novel categories
    - Authors:
        - Pam Osborn Popp
        - Prof. Ben Newell
        - Dan Bartels
        - Todd Gureckis
    - Abstract: Several recent studies have shown a positive effect of incentives on effort and attention in menial tasks such as repeated key-presses or counting numbers of objects on a screen (Dellavigna & Pope 2017; Caplin et al. 2020). If processes like effort and attention are modulated by financial incentives, is the same true of higher order cognitive abilities? We replicate a classic category learning experiment that relies on attending to relevant stimulus features to correctly distinguish two groups of objects (Shepard et al. 1961). Different group assignments of the same stimuli varied the difficulty of the task. We compare the learning and test performance between subjects across a wide range of financial incentive levels, to examine how anticipated reward influences rule generation and inductive reasoning. Our preliminary results join with several recent reports showing little to no modulation of learning performance with incentives (van den Berg, Zou, Ma 2020; Enke et al. 2021). The key emerging distinction concerning the relative effectiveness of incentives is

between cognitive tasks requiring novel insight and hypothesis discovery versus those that require rote perseverance.

**Double exponential room**

ICCM: learning

- Sampling heuristics for active function learning
    - Authors:
        - Rebekah Gelpi
        - Nayan Saxena
        - George Lifchits
        - Daphna Buchsbaum
        - Christopher Lucas
    - Abstract: People are capable of learning diverse functional relationships from data; nevertheless, they are most accurate when learning linear relationships, and deviate further from estimating the true relationship when presented with non-linear functions. We investigate whether, when given the opportunity to learn actively, people choose samples in an efficient fashion, and whether better sampling policies improve their ability to learn linear and non-linear functions. We find that, across multiple different function families, people make informative sampling choices consistent with a simple, low-effort policy that minimizes uncertainty at extreme values without requiring adaptation to evidence. While participants were most accurate at learning linear functions, those who more closely adhered to the simple sampling strategy also made better predictions across all non-linear functions. We discuss how the use of this heuristic might reflect rational allocation of limited cognitive resources.
- Learning reference birases from language input: a cognitive modelling approach
    - Authors:
        - Abigail Toth
        - Dr. Niels Taatgen
        - Jacolien van Rij
        - Prof. Petra Hendriks
    - Abstract: In order to gain insight into how people acquire certain reference biases in language and how those biases eventually influence online language processing, we constructed a cognitive model and presented it with a dataset containing reference asymmetries. Via prediction and reinforcement learning the model was able to pick up on the asymmetries in the input. The model predictions have implications for various accounts of reference processing and demonstrate that seemingly complex behavior can be explained by simple learning mechanisms
- Measuring and modelling how people learn how to plan and how people adapt their planning strategies to the structure of the environment
    - Authors:
        - Mrs. Ruiqi He
        - Dr. Falk Lieder

        - Mr. Yash Raj Jain
    - Abstract: Often we find ourselves in unknown situations where we have to make a decision based on reasoning upon experiences. However, it is still unclear how people choose which pieces of information to take into account to achieve well-informed decisions. Answering this question requires an understanding of human metacognitive learning, that is how do people learn how to think. In this study, we focus on a special kind of metacognitive learning, namely how people learn how to plan and how their mechanisms of metacognitive learning adapt the planning strategies to the structures of the environment. We first measured people's adaptation to different environments via a process-tracing paradigm that externalises planning. Then we introduced and fitted novel metacognitive reinforcement learning algorithms to model the underlying learning mechanisms, which enabled us insights into the learning behaviour. Model-based analysis suggested two sources of maladaptation: no learning and reluctance to explore new alternatives.
- Computational rational reinforcement learning: modeling the influence of product a presentation complexity
    - Authors:
        - Mr. Zeming Fang
        - Dr. Chris R. Sims
    - Abstract:In recent years, several models of human reinforcement learning have been proposed that balance rationality (maximizing expected utility) against cognitive costs. Lai and Gershman (2021) proposed a model in which the cognitive cost was assumed to be the policy complexity, defined in terms of information theory as the mutual information between the sensory input and behavioral response. Here, using evidence from a published data set (Collins & Frank, 2012), we show that this model fails to account for the "set size effect" in learning: humans' learning efficiency decreases when the number of the presented stimuli increases. We therefore propose an alternative computational model, in which cognitive cost constitutes not only the policy complexity, but also the representation complexity---the amount of information conveyed from sensory inputs to internal representations. We quantify information processing cost as the combination of representation complexity and policy complexity. The resulting model captures the set size effect in an instrumental learning paradigm.

ICCM: Memory

- An ACT-R model of order effects
    - Authors:
        - Dr. Christopher Fisher
        - Lorraine Borghetti
        - Prof. Joe Houpt
        - Christopher Adam Stevens
    - Abstract: Models based on classical probability theory have difficulty accounting for order effects, which occur when the order of question presentation affects response probabilities. Recently, quantum models have garnered support as an account of order effects. In particular, the pattern of order effects is consistent with a critical

property of the quantum model called the QQ equality. We investigate whether the ACT-R cognitive architecture can produce order effects and satisfy the QQ equality based on memory retrieval mechanisms. In the ACT-R model, the answer to the first question creates a new context through which spreading activation influences retrieval probabilities for the second answer. Our analysis shows that spreading activation can produce order effects and satisfy the QQ equality, depending on the composition of declarative memory. Across a wide range of conditions, violations of the QQ equality are typically small, but moderate to large in a smaller set of cases.

- Is similarity based interference caused by lossy compression or cue-based retrieval? A computational evaluation
    - Authors:
        - Himanshu Yadav
        - Dr. Garrett Smith
        - Shravan Vasishth
    - Abstract: The similarity-based interference paradigm has been widely used to investigate the factors subserving subject-verb agreement processing. A consistent finding is facilitatory interference effects in ungrammatical sentences but inconclusive results in grammatical sentences. Existing models propose that interference is caused either by misrepresentation of the input (representation distortion-based models) or by mis-retrieval of the interfering noun phrase based on cues at the verb (retrieval-based models). These models fail to fully capture the observed interference patterns in the experimental data. We implement two new models under the assumption that a comprehender utilizes a lossy memory representation of the intended message when processing subject-verb agreement dependencies. Our models outperform the existing cue-based retrieval model in capturing the observed patterns in the data for both grammatical and ungrammatical sentences. Lossy compression models under different constraints can be useful in understanding the role of representation distortion in sentence comprehension.
- Competence assessment by stimulus matching: an application of GOMS to asses chunks in memory
    - Authors:
        - Mrs. Hadeel Ismail
        - Prof. Peter Cheng
    - Abstract: It has been shown that in hand-written transcription tasks temporal micro-behavioral chunk signals hold promise as measures of competence in various domains (e.g., Cheng, 2014). But data capture under that an approach requires the use of graphics tablets which are relatively uncommon. In this paper we propose and explore an alternative method – Competence Assessment by Stimulus Matching (CASM). This new method uses simple mouse-driven interfaces to produce temporal chunk signals as measures of learner's ability. However, it is not obvious what features of CASM will produce effective competence measures and the design space of CASM tasks is large. Thus, this paper uses GOMS modelling in order to explore the design space to find factors that will maximize the discrimination of chunk measures of competence. Results of a pilot experiment show that CASM has

potential in using chunk signals to measure competence in the domain of English language.

- The algebra of cognitive states: Towards modelling the serial position curve
    - Authors:
        - Dr. Stefan Reimann
    - Abstract: A computational framework for modelling storage and retrieval of information in human working memory is proposed. The aim is to analyse the corresponding algebra alone, especially with regard to its congruence with empirical findings including the serial position curve. That algebra builds on the high-dimensional holographic representation of information together with two operations for computation: multiplication for binding and addition for bundling. The addition operation is inspired by basic neuronal summation and turns out to be not-associative. The non-associativity of bundling is essential. Firstly, bundling conserves sequential information; secondly, bundling implies activation gradients. Consequently, cognitive states representing a memorised list exhibit a primacy as well as a recency effect generically. The typical concave-up and asymmetrically shaped serial position curve is derived as a linear combination of those gradients. Quantitative implications of the algebra are shown to agree well with empirical data from basic cognitive tasks. This might encourage to build more full-blown models by adding further assumptions on top of this algebra.

ICCM: Space

- Predicting spatial belief reasoning: comparing cognitive and AI models
    - Authors:
        - Mr. Johannes Mannhardt
        - Dr. Leandra Bucher
        - Mr. Daniel Brand
        - Marco Ragni
    - Abstract: Spatial relational descriptions in everyday life sometimes need to be revised in the light of new information. While there are cognitive models for reasoning about spatial descriptions there are currently no models for belief revision for the spatial domain. This paper approaches this need by (i) revisiting existing models such as verbal model (Krumnack et al., 2010) and PRISM (Ragni and Knauff,2013) and adapt them to deal with belief revision tasks, (ii) evaluate these models by testing the predictive accuracy for the individual reasoner on a previously conducted experiment by Bucher et al.(2013), (iii) provide baseline models and machine learning models, provide user-based collaborative filtering and content-based filtering methods, and provide an analysis on the individual level. Implications for predicting the individual and identifying strategies and shared similar reasoning patterns are discussed
- Modelling visual decision making using a variational autoencoder
    - Authors:
        - Mr. Tyler Malloy
        - Dr. Chris R. Sims

    - Abstract: Due to information processing constraints and cognitive limitations, humans necessarily form limited representations of complex visual stimuli when making utility-based decisions. However, it remains unclear what mechanisms humans use to generate representations of visual stimuli that allow them to make predictions of utility. In this paper, we develop a model that seeks to account for the formation of representations in utility-based economic decision making. This model takes the form of a β-variational autoencoder (β-VAE) trained with a novel utility-based learning objective. The proposed model forms representations of visual stimuli that can be used to make utility predictions, and are also constrained in their informational complexity. This representation modelling approach shares common features with related methods, but is unique in its connection to utility in economic decision making. We show through simulation that this approach can account for several phenomena in human economic decision making and learning tasks, including risk averse behaviour and distortion in the calculation of expected utility.
- Cognitive modelling of a mental rotation task using a generalized spatial framework
    - Authors:
        - Kai Preuss
        - Nele Russwinkel
    - Abstract: Bespoke cognitive models of mental spatial transformation, like those used in mental rotation tasks, can generate a very close fit to human data. However these models usually lack grounding to a common spatial theory. In turn, this makes it difficult to assess their validity and impedes research insights that go beyond task-specific limitations. We introduce a spatial module for the cognitive architecture ACT-R, serving as a framework offering unified mechanisms for mental spatial transformation to try and alleviate those problems. This module combines symbolic semantic and spatial information processing for three-dimensional objects, while suggesting constraints on this processing to ensure high theoretical validity and cognitive plausibility. A mental rotation model was created to make use of this module, avoiding custom-made mechanisms in favor of a generalizable approach. Results of a mental rotation experiment are reproduced well by the model, including effects of rotation disparity and improvement over time on reaction times. Based on this, the spatial module might serve as a stepping stone towards unified, application-oriented research into mental spatial transformation.
- Modeling aperture passage affordances in ACT-R 3D
    - Authors:
        - Sterling Somers
    - Abstract: In this paper I present a model of aperture passage judgment (judgment of whether an agent can walk through aperture, rotating shoulders as needed) and performance (initiation and termination of shoulder rotation while walking through an aperture) in ACT-R 3D. The model is adapted from Somers (2016) and represents a first attempt to unify findings across multiple experiments with a single model. The cognitive model is embodied in a robotics simulator, with motor movement controlled directly by the cognitive model. The model exhibits an improved fit as compared to Somers (2016), in the same experiment. The same cognitive model also exhibits a reasonable fit in additional, exaggerated conditions.

ICCM: Interaction

- Using cognitive agents to design dynamic task allocation systems
    - Authors:
        - Dr. Christopher Fisher
        - Mary Frame
        - Christopher Adam Stevens
    - Abstract: Although cognitive models are primarily used to formalize theories of cognition, they could be applied in artificial intelligence (AI) systems, such as autonomous managers (AMs) which optimize team performance through dynamic task allocation. Cognitive models can be incorporated into the AM's decision system to understand the implications of alternative task distributions. They can also be used as simulated agents to stress test AMs under a wide range of conditions. In a simulation study, we varied the cognitive model used in the AM's decision system and the cognitive model performing a task to explore the design space of AMs. We found a trade-off between optimality and robustness in which complex models performed the best when assumptions were met, but were not robust to violation of assumptions. These results highlight the importance of considering simple models when assumptions could be violated and showcase the utility of cognitive models in AI systems.
- Understanding human social communication: a computational model of gossip
    - Authors:
        - Jeungmin Lee
        - Dr. Jerald D. Kralik
        - Jaeseung Jeong
    - Abstract: Updating people about the actions of others—social communication—is a powerful means by which humans learn about the world and maintain stable societies. However, how the mind/brain achieves this ability computationally remains unclear. Our goal is to model when, how, and why people choose to communicate information about others to others. Here we present current progress. We first describe our social communication framework, the test paradigm for model development and assessment, and an empirical experiment we conducted to obtain novel data to test model predictions. We then present our model, and compare it with two others. Our model outperformed the others, capturing the main patterns of the empirical data and matching the specific results most closely (i.e., percent of cases deciding to communicate about a target individual). Thus, our model successfully simulates human social decision-making, helping to understand how it is achieved by the human mind/brain.
- Learning basic Python concepts via self-explanation: A preliminary python ACT-R model
    - Authors:
        - Ms. Veronica Chiarelli
    - Abstract: This paper presents a cognitive modelling approach to investigating student learning of computer programming concepts via self-explanation. Self-explanation involves explaining instructional material to oneself by generating

inferences about the material. Here, we discuss the potential of self-explanation for the domain of programming and present a preliminary Python ACT-R model of novice and experienced students learning basic Python concepts via self-explanation. The model adds to knowledge of learning via self-explanation in the domain by formalizing processes involved and by acting as a base model that can be expanded to explore and simulate more aspects of this type of student learning.

- Attitudinal polarization on social networks: a cognitive architecture perspective
    - Authors:
        - Mark Orr
        - Prof. Andrea Stocco
        - Christian Lebiere
        - Don Morrison
    - Abstract: Polarization of attitudes is an important, and often troubling or disruptive, effect of interest in many fields. We seek to shed some light on how such polarization arises by applying cognitive architectures to the problem. We created a novel embedding of individual cognitive agents, using ACT-R's declarative memory model, into social networks, simulated them communicating over time, and observed the evolution of the agents' attitudes, both collectively and individually. The primary measures we use are both Shannon entropies, of the distribution of attitudes in the final configuration of the whole social network, and of the distributions of memory traces in the individual agents as the simulation progresses. Simulations were run over ten different network topologies, using three different distributions of initial attitudes, and five different values of the agents' memory decay parameter. These simulations demonstrated that polarization can be understood from a social and cognitive perspective simultaneously, each providing insights into the system's behavior.

ICCM: Bodies

- Simulating human periodic tapping and implications for cognitive models
    - Authors:
        - Mr. Pierre Gianferrara
        - Shawn Betts
        - Daniel Bothell
        - Dr. John Anderson
    - Abstract: This project's purpose was to simulate human periodic motor behavior in a simple self-paced tapping task that involved period error correction and feedback processing. When humans try to tap at a certain period, their inter-tap times are normally distributed with a standard deviation that is proportional to the period. When they try to change the period of their tapping, they do so in a single tap instead of a progressive correction taking place over multiple taps. We calibrated ACT-R's new periodic tapping motor extension based on human experimental results and showed that ACT-R can simulate human motor behavior. Future research can leverage these findings and ACT-R's periodic tapping motor extension to simulate fast-paced skilled motor behavior in complex perceptual-motor environments.

- Curiosity as pattern matching: simulating the effects of intrinsic rewards on the levels of processing
    - Authors:
        - Mr. Kazuma Nagashima
        - Dr. Junya Morita
        - Yugo Takeuchi
    - Abstract: Many studies have been conducted concerning curiosity, a type of intrinsic motivation in humans and artificial agents. However, the specifics of the correspondence between curiosity in humans and artificial agents have not yet been fully explained. This study explores this correspondence on the Adaptive Control of Thought–Rational (ACT-R) cognitive architecture by exploring situations in which curiosity effectively promotes learning. We prepared three models of path planning, representing different levels of thinking, and made them learn in multiple-breadth maze environments while manipulating the curiosity strength. The results showed that curiosity in learning an environment negatively affected the model with a shallow level of thinking. Still, it was influential in the model with a deliberative level of thinking. We consider that the results show some commonalities with human learning.
- Model-based explanation of feedback effects in syllogistic reasoning
    - Authors:
        - Mr. Daniel Brand
        - Mr. Nicolas Oliver Riesterer
        - Marco Ragni
    - Abstract: In the field of syllogistic reasoning research, a significant number of models aiming at describing the human inference processes were developed. There is profound work fitting the model's parameters and analyzing each model's ability to account for the data in order to support or disprove the underlying theories. However, the model parameters are rarely used to extract explanations and hypotheses for phenomena that go beyond the original scope of the models. In this work, we apply three state-of-the-art models, PHM, mReasoner, and TransSet, to data from reasoning experiments where participants received feedback for their conclusions. We derived hypotheses based on the models' explanations for the feedback effect and putted these to test by conducting an experiment targeting the hypotheses. The work contributes to the field in three ways: (a) the feedback effect could be replicated and was shown to be a robust effect; (b) we demonstrate the use of the model parameters in order to derive new hypotheses; (c) we present possible explanations for the feedback effect based on existing theories.
- Physio-cognitive modeling: explaining the effects of caffeine on fatigue
    - Authors:
        - Dr. Tim Halverson
        - Dr. Chris Myers
        - Dr. Jeffery Gearhart
        - Dr. Matthew Linakis
        - Dr. Glenn Gunzelmann

- Abstract: Most computational theories of cognition lack a representation of physiology. Understanding the effects of compounds present in the environment on cognition is important for explaining and predicting changes in cognition and behavior given exposure to toxins, pharmaceuticals, or the deprivation of critical compounds like oxygen. This research integrates physiologically-based pharmacokinetic (PBPK) model predictions with ACT-R's fatigue module to predict the effects of caffeine on fatigue. Parameter mapping between PBPK model parameters and ACT-R are informed by neurophysiological literature and established mappings between ACT-R modules and brain regions. Predicted caffeine concentrations in the brain are used to modulate a parameter in the fatigue module to explain caffeine's effects on multiple performance metrics.

ICCM: Individuals

- When do you buy? Predicting an individual's decision in optimal stopping problems
  - Authors:
    - Mr. Manuel Guth
    - Marco Ragni
  - Abstract: Prices, e.g., for flight tickets can change almost daily. To minimize the costs, we have to decide when to take an action, i.e., when to buy. Such decision tasks are called optimally stopping problems. This paper reconsiders the strongest cognitive models that are able to predict the average decision maker, adapts them and investigate their predictive accuracy on the individual level, i.e., how good are models in predicting when a participant decides for an action. To perform this analyses, several steps are necessary: (i) Identify data sets that provide raw data for an individual, (ii) develop an individual testing framework to assess the models, (iii) implement and adapt existing models for the individual, and (iv) consider baseline models to assess the goodness-of-fit of the models for the individual. The best and second-best models achieved an overall prediction accuracy of 85% and 84% respectively. Five of the ten examined models managed to beat a strong baseline, proving that they did in fact managed to model the individual decision process.
- How good can an individual's conclusion endorsement be predicted?
  - Authors:
    - Sara Todorovikj
    - Marco Ragni
  - Abstract: Reasoning about conditional statements is relevant in science, culture, and our everyday life. It has been shown that humans do deviate from a classical logical interpretation of conditionals. Consequently, in the past years a number of cognitive models based on Bayesian or mental model approaches have been developed, whose performance is normally judged based on their ability to fit aggregate data of participants. Here, we diverge by focusing on the individual instead. Moreover, we propose a different model testing paradigm by analyzing on an existing large data set, how good current models are in predicting an endorsement of an individual reasoner on a scale from 0 to 100%. Towards this goal we reanalyze the data by rigorously distinguishing between test and training data set, by making existing models for conditional reasoning predictable such as the Dual Source Model (Singmann, Klauer, & Beller, 2016) and a model by Oaksford, Chater, and Larkin

(2000). We also implement a modeling idea of Pearl based on possible worlds. We can show that all three models perform equally good in predicting an individual reasoner's endorsement and that they meet an empirical baseline (the median of the most frequent answer). A discussion on the gained insights in understanding conditional reasoning concludes the paper.

- Towards precise measures of individual performance in complex tasks
    - Authors:
        - Roussel Rahman
        - Wayne D. Gray
    - Abstract:Simple laboratory tasks typically allow one or a few methods of task performance. In contrast, moderately complex tasks, such as video games, provide many methods of task performance which, in essence, provide many ways of completing the task without necessarily completing all possible components. Although performance on complex tasks improves with practice, the improvements do not represent the simple effects of power-law learning but, rather, they tend to reflect the discovery and practice of a diverse set of methods. Understanding what we see during complex task learning, requires us to evaluate individual performance against benchmarks of optimality. In this report, we use the game of Space Fortress (SF) as a complex experimental paradigm in which we demonstrate two alternative measures that reveal scopes of individual differences in the discovery and implementation of an optimal method that would be missed by traditional measures of the game.
- Estimating individual differences in working memory through ACT-R modeling and resting state connectivity
    - Authors:
        - Patrick Rice
        - Prof. Andrea Stocco
    - Abstract: A complete and holistic understanding of human cognition should be able to relate idiographic parameters representing cognitive functioning to interactions between connected brain networks identified by neuroimaging methods. Here, using the ACT-R cognitive architecture, we examine the possibility of producing idiographic parameterizations of cognitive functioning in a task environment and show that these parameterizations produce reasonable predictions of individual behavior. We then demonstrate a method of determining a subset of parameters that are adequate for prediction of behavior before confirming that the most critical of these task-based parameters is related to functional connectivity measures in individual resting-state fMRI data.

ICCM: Poster session

- Timing and structure of reward information influences bias in perceptual decisions as revealed by a hierarchical drift diffusion model
    - Authors:
        - Dr. Manisha Chawla
        - Prof. Krishna Miyapuram

- Abstract: Differential payoffs can bias simple perceptual decisions. Drift Diffusion models (DDM) have been successfully used to simultaneously model for response times (RTs) and accuracy of binary decisions. The DDM allows for identification of latent parameters that represent psychological processes underlying perceptual decisions. These parameters characterize decision making as a noisy process that accumulates evidence towards one of the two boundaries. Previous research in two alternative forced choice (2AFC) experiments has found that asymmetric payoffs result in a bias towards those decisions that result in higher payoff. We manipulate the reward structure resulting in symmetric and asymmetric payoffs for a simple orientation discrimination task and test for the differences in parameters of drift diffusion model that might relate to reward-induced bias in perceptual decisions. To understand the mechanisms of how reward information might be integrated with perceptual decisions, we altered the relative timing i.e. processing order of reward information and perceptual stimuli.Computational modelling using a hierarchical DDM revealed starting point bias towards stimuli oriented in the direction of higher rewards in asymmetric as well as symmetric rewards.The drift rate reflected the average reward expectation when reward information was presented before, but not after the perceptual stimulus. Our results suggest that integration of rewards with perceptual decisions is mediated by modulating motivation for evidence accumulation over time and prior bias in starting point.

- Parameter correlations in the predictive performance equation: Implications and solutions
  - Authors:
    - Mr. Michael Collins
    - Florian Sense
    - Michael Krusmark
    - Joshua Fiechter
    - Tiffany (Jastrzembski) Myers
  - Abstract: Research of mathematical models of learning and retention have focused on accounting for an individual's performance across a variety of learning schedules (i.e., spaced and massed). The attempted goal of such research is to develop a model which can adequately predict human performance across a range of learning scenarios. However, little attention of this model development has focused on the interpretation of a model's best fitting parameters given the structure of a model's equations and its predicted performance values. The effect of this can lead to the development of models where the parameter values are correlated hindering a theoretical interpretation of performance. Here we examine the structure of the Predictive Performance Equation (PPE) and highlight portions of PPE's equations that lead to correlations across its free parameters. We propose a fix for these issues (Modified PPE) and conduct a formal model comparison showing the Modified PPE is simpler, has less parameter correlation and its best fitting parameters map on to identifiable aspects of an individual's performance.
- Applications of information theory to perceptual independence and separability
  - Authors:
    - Mikaela Akrenius

    - Abstract: Despite of strong historical connections between information theory and the study of perceptual independence and separability, few modern approaches take advantage of these connections. We revive Garner and Morton's (1969) classic Mutual Uncertainty Analysis (MUA), complement it with Partial Information Decomposition (PID, Williams & Beer, 2010), and apply both to a sample of data from contemporary studies. While existing theories can dissociate between perceptual and decisional separability and identify dependencies at the level of individual stimuli, PID can provide analogous diagnostics for identifying the existence of perceptual independence and separability, decompose them into their constituents, and provide a measure for their strength.
- A predictive processing implementation of the common model of cognition
    - Authors:
        - Dr. Alex Ororbia
        - Dr. Alex Kelly
    - Abstract: We present how a cognitive architecture can be built from the neural circuit models proposed under the frameworks of holographic memory and neural generative coding. Specifically, we draw inspiration from well-known cognitive architectures such as ACT-R, Soar, Leabra, and Nengo, as well as the common model of cognition, to propose the kernel that might drive a complex, modular system that would prove useful for developing intelligent agents that tackle statistical learning tasks, as well as for answering questions and testing hypotheses in cognitive science and computational neuroscience.
- Prediction advantage as retrieval interference: an ACT-R model of processing possessive pronouns
    - Authors:
        - Umesh Patil
        - Sol Lago
    - Abstract: We propose a retrieval interference-based explanation of a prediction advantage effect observed in Stone et al. (in press). They reported two dual-task eye-tracking experiments in which participants listened to instructions involving German possessive pronouns, e.g. 'Click on his blue button', and were asked to select the correct object from a set of objects displayed on screen. Participants' eye movements showed predictive processing, such that the target object was fixated before its name was heard. Moreover, when the target and the antecedent of the pronoun matched in gender, predictions arose earlier than when the two genders mismatched — a prediction advantage. We propose that the prediction advantage arises due to similarity-based interference during antecedent retrieval, such that the overlap of gender features between the antecedent and possessum boosts the activation level of the latter and helps predict it faster. We report an ACT-R model supporting this hypothesis. Our model also provides a computational implementation of the idea that prediction can be thought of as memory retrieval. In addition, we provide a preliminary ACT-R model of changes in visual attention as a result of language processing.
- Collective intelligence as latent imagination

- Authors:
  - Amit Singh
- Abstract: Intelligence is fundamentally the ability for an agent to infer causal dependencies in its environment. However, the precise conceptualization across systems and scales is a polemical question. The concept of “Intelligence” may as well refer to a quantitative measure of formal cognitive ability than to a qualitative property of skilled agency. This difficulty in understanding the concept compounds when we try to scale to descriptive and predictive models of collective behavior. While it is self-evident that groups may leverage pairwise interactions or their collective resources to tackle complex problems, is that process only the sum of individual intelligences or is the group intelligent in its own right? If the latter, what does it mean for the classical internalist conception of intelligence and agency? If the former, then what is the proper scale of analysis in systems of nested organization, such as human societies? This question can be approach rigorously through a non-reductive account of the physical processes underlying intelligence. Here I propose that the latent model framework(with active inference as intrinsic reward mechanism) framework is a promising approach that could live up to the multiple dimensions of adeptness required by any framework that would attempt to generalize cognition across scales. A statistical state model for mathematical state transitions can be built and can be used to define cognitive models like causation and correlation.

- Derivation of metric scales from ordinal data with Guttman-Goode’s scaling
  - Authors:
    - Dr. Vithor Franco
  - Abstract: Psychometric methods have been argued to not be able to test the assumption that the underlying latent scale is really an interval scale. More specifically, the Rasch model was accused to provide an interval scale only because it fits measurement error, an issue known as the "Rasch paradox". Regardless of whether the Rasch paradox is real or not, it would be interesting to be able to derive interval, or even ratio, scales from ordinal data. The aim of the present study is to propose a procedure that combines the probabilistic Guttman scaling with Goode’s method to obtain either an interval or a ratio scale from dichotomous psychometric data. We present how the procedures are combined to derive the metric scales and how fit to the data can be calculated using RMSE. Final considerations note the limitations of the procedure, but also value its potentials.
- Structure learning as a mechanism for overharvesting
  - Authors:
    - Nora Harhen
    - Dr. Aaron Bornstein
  - Abstract: In patch leaving problems, foragers must decide between engaging with a currently available, but depleting, patch of resources or foregoing it to search for another, potentially better patch. Overharvesting, or staying in the patch longer than what is optimally prescribed, is widely observed in these problems. Most previous explanations for this phenomenon focus on how foragers’ mis-estimations of the environment could produce overharvesting. They suggest that if the forager correctly learned the environment’s quality, then they would behave according to Marginal

Value Theorem (MVT). However, this proposal rests on the assumption that the forager has full knowledge of the environment's structure. Rarely does this occur in the real world. Instead, foragers must learn the structure of their environment. Here, we model foragers as pairing an optimal decision rule with an optimal learning procedure that allows for the possibility of heterogeneously-structured (i.e. multimodal) reward distributions. We then show that this model can appear to produce overharvesting, as measured by the common optimality criterion, when applied to the usual tasks, which employ homogeneous reward distributions. This model accounts for behavior in a previous serial stay/leave task, and generates novel predictions regarding sequential effects that agree with participant behavior. Taken together, these results are consistent with overharvesting reflecting optimality with respect to a different set of conditions than MVT and suggests that MVT's definition of optimality may need to be adjusted to account for behavior in more naturalistic contexts.

- Diverse experience leads to improved adaptation: An experiment with a cognitive model of learning
    - Authors:
        - Chase McDonald
        - Cleotilde (Coty) Gonzalez
        - Dr. Leslie Blaha
        - Christian Lebiere
        - Joshua Fiechter
        - Erin Bugbee
        - Erin N McCormick
    - Abstract: In dynamic decision tasks, the situations we confront are never the same: the world is constantly changing. Generally, our ability to generalize learned skills depends on the similarity between the learned skills and the situations in which we will apply those skills. However, in dynamic tasks, the situations we are trained in will most likely be different from the situations in which we need to apply skills. For example, in the face of emergencies, one could be trained to handle hypothetical disaster scenarios, but remain unprepared for the emergency that is actually experienced. How can we best prepare for the unexpected? Cognitive Science research suggests that heterogeneity during training helps people's adaptation to unexpected situations. However, evidence for a general diversity hypothesis is limited. In this research, we investigate this Diversity Hypothesis using a cognitive model of learning and decisions from experience based on Instance-Based Learning (IBL) Theory. We focus on the concept of decision complexity to investigate whether confronting decisions of diverse complexities results in improved adaptation to unexpected decision complexities, compared to situations of consistent decision complexity. We conduct a simulation experiment using an IBL model in a Gridworld task, and expose agents to learning various degrees of diversity; we then observe how these agents transfer their acquired knowledge to a novel decision complexity situation. Our results support the Diversity Hypothesis and the benefits of diversity on adaptation.
- Sequential effects in non-sequential tasks

    - Authors:
        - Nidhi Banavar
        - Michael Lee
        - Dr. Aaron Bornstein
    - Abstract: In behavioral economic experiments with randomized, or unstructured choice sets, trial-level sequential dependencies at the level of choice behavior or reaction time are usually assumed not to be present in behavior, and thus not explicitly accounted for. We present a flexible Bayesian hierarchical model that allows us to test for the presence or absence of linear stimulus-driven sequential effects on parameters of interest and subsequent choice. We apply this model to two data sets: one intertemporal choice and one risky decision making. We demonstrate sequential effects on risk tolerance inference and on deliberative evaluation of discounted value. Our results show that data collected in sequence cannot, without first verifying this assumption, be treated as if it were collected independently.
- Modeling phishing susceptibility as decisions from experience
    - Authors:
        - Dr. Edward Cranford
        - Kuldeep Singh
        - Palvi Aggarwal
        - Cleotilde (Coty) Gonzalez
        - Christian Lebiere
    - Abstract: Traditional anti-phishing training is often non-personalized and does not typically account for human experiential learning. However, to personalize training, one requires accurate models and predictions of individual susceptibility to phishing emails. The present research is a step toward this goal. We propose an Instance-Based Learning model of phishing detection decision-making, constructed in the ACT-R cognitive architecture. We demonstrate the model's ability to predict behavior in a frequency training study, and its generality by predicting behavior in another phishing detection study. The results shed additional light on human susceptibility to phishing emails and highlight the effectiveness of modeling phishing detection as decisions from experience. We discuss the implications of these results for personalized anti-phishing training.
- Towards benchmarking cognitive models: A Python library for modular environment specification and partial model generation in ACT-R
    - Authors:
        - Emmanuelle Dietz
        - Oliver Klaproth
    - Abstract: In this paper we present the cognitive modeling library txt2actr, which facilitates the specification of an ACT-R environment through simple text files and partially automates the construction of certain components within a cognitive model. Our general purpose goes beyond this library and aims at promoting the modular parametrization and systematic evaluation for cognitive models. In particular, we suggest to establish benchmarks that allow (i) the competition among models with respect to classical tasks in experimental psychology, and (ii) the evaluation of

possibly new or more applied tasks with respect to benchmark models. Such benchmarking proposals can be found in various other disciplines and usually serve as an incentive to improve existing theories and eventually converge towards a common language. Yet, txt2actr is far from providing a solution to the associated challenges. It rather serves as a proof of concept by illustrating how two model components for very specific cognitive phenomena in situation awareness can be applied in three different environments.

- Exploring the decision component of the Activation-Decision-Construction-Action Theory for gain and loss facing scenarios
    - Authors:
        - Dr. Tei Laine
        - Dr. Tomi Silander
    - Abstract: Inspired by Masip et al.'s (2016) test of ADCAT model's decision component, we wanted to see if we could replicate their findings using different data from a similar scenario-based study. They found that expected value of telling the truth predicted the decisions to lie or tell the truth more accurately than the expected value of lying, and even better than the motivation to lie, which they defined as a difference between these two expected values. In contrast, in our modeling study the motivation to lie was the best predictor of choices for both actual liars and truth tellers in conditions involving gains and large losses, whereas only in the condition involving large losses the expected value of telling the truth outperformed the expected value of lying. We conclude that whether the participants could gain something or avoid losing something by deceiving determined if they focused on benefits of lying or costs of telling the truth.
- Lessons learned from modelling situated cognitive agents interacting with a dynamic environment
    - Authors:
        - Lukas Seiling
        - Maximilian Plitt
        - Paul Schweidler
        - Oliver Klückmann
        - Lilian Befort-Trier
        - Robin Konczir
        - Severin Reuter
        - Kai Preuss
        - Sebastian Wiese
        - Nele Russwinkel
    - Abstract: The study of knowledge representations and reasoning problems faced by a cognitive agent interacting with a dynamic and incompletely known world is relevant to cognitive robotics and understanding complex cognition and related fields. The paper introduces four cognitive agents that were modeled in a student project with specific requirements. The cognitive architecture ACT-R was used to model flexible agents that interact with objects in a grid field with only a limited field of view. Long-term planning is not possible here: the meaning of objects needs to be

discovered and the field explored to find the goal as quickly as possible. The project demonstrates how the four agents learn from interactions and what information needs to be kept available to flexibly decide in unpredictably occurring situations. All four agents are shortly described in more detail. The project covers on a small scale some aspects that are crucial for autonomous agents in a simple game environment. The four agents are faced with 15 challenge environments that need to be explored and managed. The challenge performance results show that a higher number of productions does not necessarily lead to better performance.

- A drift-diffusion model to explain vehicle deceleration detection of vulnerable road users
    - Authors:
        - Daniel Trommler
        - Claudia Ackermann
        - Josef Krems
    - Abstract: The development of automated vehicles is accompanied by the question of how this technology will interact with vulnerable road users (VRUs; e.g. pedestrians, cyclists). Especially in shared spaces, implicit communication signals, such as vehicle deceleration, proved to be crucial. However, previous studies on the parameterization of vehicle deceleration indicated that human detection of vehicle deceleration may depend on various situational and individual factors. This research has two aims: (1) We want to investigate how the detection and perceptual decision-making on vehicle deceleration can be formally described using a cognitive model. For this, we discuss the applicability of a drift-diffusion model (DDM). (2) Further, we will follow up on previous research regarding the influence of different situational and individual factors on the detection performance and discuss how these factors could be related to the DDM parameters. With this research, we would like to contribute to a better understanding and a consistent, formal description of different factors influencing the detection of vehicle deceleration. This could be associated with improved interaction between automated vehicles and VRUs.
- Individualizing a biomathematical fatigue model with attention data
    - Authors:
        - Dr. Bella Veksler
        - Dr. Megan Brianne Morris
        - Dr. Glenn Gunzelmann
    - Abstract: Fatigue is a problematic factor in many workplace environments, resulting in safety and health risks that require monitoring and management. One means to monitor and manage fatigue is through the use of tools implementing biomathematical fatigue models to create assessment and predictions of operator fatigue based on sleep habits. Unfortunately, these models tend to provide assessments and predictions for an “average” operator given work schedules, lacking individualization. One way in which these models can be individualized is through the use of at-the-moment performance data that can modulate the model estimates. In the current effort, we describe an initial attempt at developing an algorithm to individualize fatigue assessments and predictions from a widely-used biomathematical fatigue model with performance data from a common attention task. We discuss the sleep dataset used for the effort, scaling procedure, and model fitting

using a genetic algorithm. We then discuss future directions we will take to further increase the effectiveness and efficiency of the individualization capability and its implications.

- How much context is helpful for noun and verb acquisition?
    - Authors:
        - Raquel G. Alhama
        - Caroline Rowland
        - Evan Kidd
    - Abstract: While it is widely accepted that children use distributional information to acquire multiple components of language, the underpinnings of these achievements are unclear. The goal of the current work is to investigate the role of linguistic context in the acquisition of nouns and verbs. In particular, we use a Distributional Semantic Model (DSM) to predict the age of acquisition of nouns and verbs, and we analyse the hyperparameters of the model to find out how much context is helpful for the acquisition of these words. DSMs have been extensively evaluated against human adult ratings on semantic associations, but less so against children's emerging semantic representations. For reasons of space, we limit our review of prior work to the most recent study that is closest to our goals. In that study, Alhama et al. (2020) propose two methods to evaluate DSMs for children's acquisition of nouns. Their results suggest that the Skipgram version of word2vec (Mikolov et al., 2013) is most successful in predicting the Age of Acquisition (AofA) of nouns. In our work, we look more in-depth into the hyperparameters of Skipgram that best predict AofA, to find out more about the influence of context in acquisition. In addition, we extend the study to verbs.
- Criticality perception in dynamic traffic scenarios: an ACT-R model
    - Authors:
        - Noémi Földes-Cappellotto
        - Moritz Held
        - Martin Baumann
        - Ms. Tanja Stoll
    - Abstract:Evaluating criticality in driving is of utmost importance, especially in dynamic driving scenarios such as lane changing. Current theories assume that drivers' evaluation process is based on perception of time-to-collision (TTC). We argue that determining whether a situation is critical or not is guided by retrieving memories containing the perceived situation elements. This memory retrieval helps drivers build up situation awareness and it takes place regardless of whether participants possess a memory which is a perfect match to the scenario at hand, or only a partially matching one, including some of the situation's elements. Therefore, memory retrieval leads to a more or less reliable situation model (SM) and anticipation about how the scenario is going to develop. Furthermore, we assume that drivers' SM also includes the SM of a potentially relevant road user (i.e., one that might interfere with the driver) to some extent as well. We are creating an ACT-R model in order to explore perception and memory retrieval which result in a perceptual decision participants make about the situation's criticality in a highly dynamic lane-changing scenario.

- Simulating proficiency and exposure effects on cross-language structural priming in simultaneous bilinguals
    - Authors:
        - Mr. Yung Han Khoe
        - Gerrit Jan Kootstra
        - Prof. Rob Schoonen
        - Stefan Frank
    - Abstract: Bilingual speakers are more likely to use a syntactic structure in one language if they have recently encountered that same structure in another language. This cross-language structural priming effect is predicted to be positively modulated by second language proficiency according to a developmental account by Hartsuiker and Bernolet (2017). We propose to extend this account from sequential bilinguals to simultaneous bilinguals. In this latter group, syntactic structures develop in parallel and can integrate from the onset. Therefore, we do not expect proficiency or other measures of development, such as exposure, to modulate cross-language structural priming in these bilinguals. In simulated cross-language structural priming experiments, we explored how proficiency affects priming of transitives. We use an implicit learning model of sentence production to model the simultaneous English-Spanish bilinguals in these simulations. Furthermore, we investigated whether the priming effect is modulated by exposure to the non-dominant language, which only Kutasi et al. (2018) also analyzed. We found no evidence for any modulating effects for either proficiency or exposure, which is in line with the previously reported behavioral result of Kutasi et al. (2018). Together, our modeling results and Kutasi et al.'s (2018) behavioral results support an extended version of the developmental account of cross-language structural priming that predicts a modulating effect of proficiency in sequential bilinguals, but not in simultaneous bilinguals.
- Utilizing ACT-R to investigate interactions between working memory and visuospatial attention while driving
    - Authors:
        - Moritz Held
        - Dr. Jelmer Borst
        - Dr. Anirudh Unni
        - Prof. Jochem Rieger
    - Abstract: In an effort towards improving the safety in everyday traffic, adaptive automation has emerged as a promising technology in recent years. A key step in this approach is the accurate prediction of momentary cognitive workload while driving. Previous research has found an interaction between working memory load and visuospatial attention complicating the accurate prediction for these cognitive concepts. We have developed an ACT-R model to investigate the nature of the interaction and improve the prediction accuracy for working memory load and visuospatial attention while driving. This ACT-R model is driving on a multi-lane highway with concurring traffic and alternating lane-widths while doing a secondary n-back task using speed signs. Furthermore, it is able to handle complex driving situations like overtaking traffic and adjusting its speed according to the n-back task.

The behavioral results show an increase in error rates in the secondary task with increasing n-back difficulty as well as a decrease in driving performance with increasing difficulty in the n-back task. The results of the model indicate an interaction at a common task-unspecific level.

- On disjunctions and the weak completion semantics
    - Authors:
        - Islam Hamada
        - Steffen Hölldobler
    - Abstract: The weak completion semantics is a three-valued, non-monotonic theory which has been shown to adequately model various cognitive reasoning tasks. In this paper we extend the weak completion semantics to model disjunctions and exclusive disjunctions. Such disjunctions are encoded by integrity constraints and skeptical abduction is applied to compute logical consequences. We discuss various examples and relate the approach to the elimination of disjunctions in the calculus of natural deduction.
- A cognitive computational model of collective search with social information
    - Authors:
        - Sabina J. Sloman
        - Dr. Robert Goldstone
        - Cleotilde (Coty) Gonzalez
    - Abstract:Many of the decisions we make in day-to-day life are made on the basis of incomplete information. The experiences of members of our social network are often an important source of decision-relevant information. In a 2008 experiment, Mason, Jones, and Goldstone showed that a person's social network structure can have an impact on their success at identifying the optimal decision given incomplete information: Members of more interconnected networks excelled at easier tasks, while members of more dispersed networks did comparatively well when the task was more difficult. Drawing on these results, we synthesize work from various areas of cognitive science into a computational cognitive model of search in a social context: the Social Interpolation Model (SIM). The SIM incorporates three avenues for individual difference, or free parameters: breadth of generalization, degree of optimism, and degree to which personal experience is weighted more heavily than the experiences of others. We report the results of simulations of interacting agents who are embedded in the same task structure as the one designed by Mason et al. (2008) and whose behavior is determined by the SIM. Based on these simulation results, we discuss qualitative effects of varying each of the SIM's free parameters in the context of different social network structures. Our work highlights interaction effects between information-processing biases, social context and task structure on agents' success at identifying the optimal solution.
- People are insensitive to within-category feature correlations in categorization
    - Authors:
        - Florian Seitz
        - Dr. Jana Jarecki
        - Jorg Rieskamp

- Abstract: This work compares two types of psychological similarity in categorization. Similarity is a central component of categorization theories. Exemplar theories, for instance, assume that people categorize new exemplars based on their similarity to previous category members. Traditionally, the underlying psychological similarity is based on the sum of two exemplars' squared feature value differences (Euclidean similarity). The Euclidean similarity, however, ignores the distribution of exemplars within categories by assuming uncorrelated features within categories. The Mahalanobis similarity, in turn, extends the Euclidean similarity by accounting for within-category feature correlations. Results from machine learning have shown that in categorization problems involving correlated features within categories, the Mahalanobis similarity can outperform the Euclidean similarity. On the empirical side, results from psychology indicate that people can be sensitive to within-category feature correlations: Some findings suggest a general sensitivity for within-category feature correlations, yet others have argued that this sensitivity depends on the category structure, task format, and amount of training. The present work rigorously tested the correlation-insensitive Euclidean similarity against the correlation-sensitive Mahalanobis similarity to investigate if people use within-category feature correlations in categorization.

ICCM: Architectures

- The structured mind at rest: Evidence for the "Common Model of Cognition" in resting state fMRI
  - Authors:
    - Dr. Catherine Sibert
    - Prof. Andrea Stocco
    - Holly Hake
  - Abstract: The Common Model of Cognition (CMC) has been proposed as a high level framework through which functional neuroimaging data can be predicted and interpreted. Previous work has found the CMC is capable of predicting brain activity across a variety of tasks, but it has not been tested on resting state data. This paper adapts a previously used method for comparing theoretical models of brain structure, Dynamic Causal Modeling (DCM), for the task-free environment of resting state, and compares the CMC against six alternate architectural frameworks. For a large sample of subjects from the Human Connectome Project (HCP), the CMC provides the best account of resting state brain activity, suggesting the presence of a general purpose structure of connections in the brain that drives activity when at rest and when performing directed task behavior.
- Toward undifferentiated cognitive models
  - Authors:
    - Dr. Colin Kupitz
    - Aaron Eberhart
    - Daniel Schmidt
    - Christopher Adam Stevens
    - Dr. Cogan Shimizu
    - Prof. Pascal Hitzler

        - Dario Salvucci
        - Dr. Benji Maruyama
        - Dr. Chris Myers
    - Abstract: Autonomous systems are a new frontier for pushing sociotechnical advancement. Such systems will eventually become pervasive, involved in everything from manufacturing, healthcare, defense, and even research itself. However, proliferation is stifled by the high development costs and the resulting inflexibility of the produced systems. The current time needed to create and integrate state of the art autonomous systems that operate as team members in complex situations is a 3-15 year development period, often requiring humans to adapt to limitations in the resulting systems. A new research thrust in interactive task learning (ITL: Laird et al., 2017) has begun, calling for natural human-autonomy interaction to facilitate system flexibility and minimize users' complexity in providing autonomous systems with new tasks. We discuss the development of an undifferentiated agent with a modular framework as a method of approaching that goal.
- Inferring a cognitive architecture from multi-task neuroimaging data: A data-driven test of the common model of cognition using granger causality
    - Authors:
        - Holly Hake
        - Dr. Catherine Sibert
        - Prof. Andrea Stocco
    - Abstract: A common complaint levied at analyses based on cognitive architectures is their lack of connection to observed functional neuroimaging data, particularly for architectural models that rely on high level, theoretical components of cognition. Previous work has connected task-based functional MRI data to the Common Model of Cognition (CMC), using a top-down modeling approach. Here, a bottom-up method, Granger Causality Modeling (GCM), is applied to the same task-based data to infer a network of causal connections between brain regions based on their functional connectivity. The resulting network shares many connections with those proposed by the Common Model.
- Individual differences in decision making strategies can be predicted by resting-state functional connectivity
    - Authors:
        - Cher Yang
        - Prof. Andrea Stocco
        - Dr. Catherine Sibert
    - Abstract: As the study of individual differences becomes more widespread, questions arise about the reasons that a particular individual might adopt a particular strategy. Using both the behavioral and functional neuroimaging data of healthy adults from Human Connectome Project (HCP) we examined decision making in an incentive processing task (Delgado et al. 2000). A pair of distinct ACT-R models, representing a Declarative strategy and a Procedural strategy, were used to classify subjects as either Declarative or Procedural decision makers based on their behavioral data. A machine learning Lasso analysis was performed on each subject's

resting state functional connectivity, and was able to match the ACT-R model classifications to a high degree of accuracy. This suggests that the strength of connections between brain regions may play an important role in shaping the decision making process of a given individual.

ICCM: Processes

- Capturing dynamic performance in a cognitive model: Estimating ACT-R memory parameters with the linear ballistic accumulator
    - Authors:
        - Maarten van der Velde
        - Florian Sense
        - Dr. Jelmer Borst
        - Hedderik van Rijn
    - Abstract: The parameters governing our behaviour are in constant flux. Accurately capturing these dynamics in cognitive models poses a challenge to modellers. Here, we demonstrate a mapping of ACT-R's declarative memory onto the linear ballistic accumulator, a mathematical model describing a competition between evidence accumulation processes. We show that this mapping provides a method for inferring individual ACT-R parameters without requiring the modeller to build and fit an entire ACT-R model. We conduct a parameter recovery study to confirm that the LBA can recover ACT-R parameters from simulated data. Then, as a proof of concept, we use the LBA to estimate ACT-R parameters from an empirical data set. The resulting parameter estimates provide a cognitively meaningful explanation for observed differences in behaviour over time and between individuals.
- A hidden semi-markov model classifier for strategy detection in multiplication problem solving
    - Authors:
        - Leendert Van Maanen
        - Mr. Ernö Groeneweg
        - Dr. Kim Archambeau
    - Abstract: Self-report as a tool to understand different cognitive processing strategies has been criticised for decades, but to date there have not been many alternatives. To remedy this hiatus, we propose to apply a recently developed method for processing stage analysis (Hidden semi-Markov Model Multivariate Pattern Analysis, HsMM-MVPA) to a cognitive strategy prediction task. HsMM-MVPA uses specific patterns in EEG data to determine the most likely number of sequential processing stages. Under the assumption that cognitive processing strategies differ in the number of stages, we constructed a classifier using fitted HsMM-MVPA to try and differentiate between two cognitive strategies in unseen data. The method is applied to data from a multiplication verification task, in which participants are asked to verify the truth of a solution to a multiplication problem (3 x 9). We asked participants to indicate via self-report whether they knew the answer by heart (Strategy 1, Retrieval) or needed to compute the answer (Strategy 2, Procedural). The classifier could predict the self report labels above chance, suggesting that the number of processing

stages identified using EEG can be used to track the cognitive processing strategy that are in use throughout a task.

- Covering strategy changes: From System 1 to System 2 in syllogistic reasoning
    - Authors:
        - Ms. Evelyn Wiens
        - Dr. Alice Ping Ping Tse
        - Marco Ragni
    - Abstract: Most cognitive models for human syllogistic reasoning aim to explain an average reasoner, i.e., the responses given by aggregating the response of the majority of reasoners. Studies show that individuals can deviate a lot from this average reasoner. So far, there have been very few models to explain and predict the responses of individual reasoner. In empirical studies, it can be observed that participants often rely on heuristic strategies (System 1 processes) to solve syllogistic problems but participants switch to analytical strategies (System 2 processes) occasionally. The study by Tse et al. (2014) demonstrated that inhibition of the matching heuristic is necessary to switch to the analytical processes in conflict problems that the output from the heuristic does not agree with that from analytical processes. This paper presents four mechanisms to incorporate individual differences in reasoning strategies and effect induced by problem type of the syllogism in predictive computational models built according to the mental model theory, mReasoner, and verbal models theory. Among these models, the composite model, which takes the highest accuracy model for individual reasoner, can reach a median accuracy of 86% in predicting the conclusions given by individual reasoner in the study
- Validating and refining cognitive process models using probabilistic graphical models
    - Authors:
        - Laura Hiatt
        - Connor Brooks
        - Greg Trafton
    - Abstract: We describe a new approach for developing and validating cognitive process models. In our methodology, graphical models (specifically, hidden Markov models) are developed both from human empirical data on a task, as well as from synthetic data traces generated by a cognitive process model of human behavior on the task. Differences between the two graphical models can then be used to drive model refinement. We show that iteratively using this methodology can unveil substantive and nuanced imperfections of cognitive process models that can then be addressed to increase their fidelity to empirical data.

**Hal-normal room**

Risk Taking

- A Bayesian method for measuring risk propensity in the Balloon Analogue Risk Task
    - Authors:
        - Jeff Coon
        - Michael Lee

- Abstract: The Balloon Analogue Risk Task (BART) is widely-used to measure risk propensity in theoretical, clinical, and applied research. In the task, people choose either to pump a balloon to increase its value at the risk of the balloon bursting and losing all value, or to bank the current value of the balloon. Risk propensity is most commonly measured as the average number of pumps on trials for which the balloon does not burst. Burst trials are excluded because they necessarily underestimate the number of pumps people intended to make. However, their exclusion discards relevant information about people's risk propensity. A better measure of risk propensity uses the statistical method of censoring to incorporate all of the trials. We develop a new Bayesian method, based on censoring, for measuring both risk propensity and behavioral consistency in the BART. Through applications to previous data we demonstrate how the method can be extended to consider the correlation of risk propensity with external measures, and to compare differences in risk propensity between groups. We provide implementations of all of these methods in R, MATLAB, and the GUI-based statistical software JASP.

- Exploring dual-process models of the Balloon Analogue Risk Task
  - Authors:
    - Ran Zhou
    - Prof. Jay I. Myung
    - Mark Pitt
  - Abstract: People are often faced with repeated risky decisions that involve uncertainty. In sequential risk-taking tasks, like the Balloon Analogue Risk Task (BART), the underlying decision process is poorly understood. Accurate depiction of the task requires modeling the mental representation of the object or the problem in the task environment and the cognitive processes operating on these representations to produce responses. Dual-process theory proposes that human cognition involves two main families of processes, often referred to as System 1 (fast and automatic) and System 2 (slow and conscious). We crossed models of the BART with different assumptions about the interaction between the two systems (serial vs. parallel), and built a pool of computational dual-process models with varying representations and process configurations. This model framework was designed to explain both choice and response time data in the BART. A model comparison study examined the statistical properties of the models (i.e., parameter recovery, model recovery, and predictive accuracy). The best-performing subset of models was then evaluated by fitting them to data collected in three experiments whose manipulations were intended to engage the two systems in different ways. Results showed that the model assuming simultaneously activated two systems, a drift rate influenced by experience, and an evaluation process based on frequency representation, outperformed the others. Findings shed light on how modeling multiple processes and representations can benefit our understanding of sequential risk-taking behavior.
- When a gain becomes a loss: The effect of wealth predictions on financial decisions
  - Authors:
    - Jennifer Trueblood
    - Dr. Abigail Sussman

- Abstract: When people make financial decisions, they need not only think about their current financial situation, but also about changes in future wealth. This work investigates people's beliefs about their future wealth and how these beliefs impact financial decisions. Using a joint experimental and computational cognitive modeling approach, we show that people's future beliefs serve as reference points when making investment decisions. These results are further supported by data from a large-scale cross-sectional survey (n = 4,606) showing that people's beliefs about the future value of their assets are related to investment decisions between risky (i.e., stock market index) and safe (i.e., bond earning a fixed amount per year) options. In both the experiments and survey, we hypothesize that outcomes that are nominally stated as sure gains can become coded as losses due to belief-based reference points. This pattern leads to an increase in riskier choices across positive outcomes for individuals with optimistic beliefs about their future wealth.

- The role of reward and punishment learning in externalizing adolescents: A joint generative model of traits and behavior
  - Authors:
    - Dr. Nathaniel Haines
    - Dr. Avantika Mathur
    - Dr. Brandon Turner
    - Theodore Beauchaine
    - Dr. James Blair
  - Abstract: Reinforcement learning is hypothesized to play a strong role in the development and maintenance of impulsivity-related (or externalizing) disorders across the lifespan. For children with the hyperactive-impulsive presentation of Attention-Deficit/Hyperactivity Disorder (ADHD-HI), blunted sensitivity to reward is thought to produce subjective states of irritability and negative affect, which evoke excessive approach behaviors that function to down-regulate negative affect. Blunted sensitivity to punishment is thought to produce impaired extinction/reversal learning of previously reinforced action-outcome contingencies, in addition to a general lack of risk aversion. Combined, blunted reward and punishment sensitivity can potentiate aggressive and antisocial behaviors, setting a developmental course for Oppositional Defiant Disorder, Conduct Disorder, Substance Use Disorders, and Antisocial Personality Disorder. In the current study, we examine the relationships between (1) cognitive mechanisms underlying reinforcement learning on a passive avoidance paradigm, (2) neural responses to feedback collected with task-based fMRI, and (3) trait measures of externalizing and internalizing psychopathology, within a sample consisting of control adolescents (n=66), and those diagnosed with externalizing (n=134) and/or internalizing (n=74) disorders (comorbid n=67). We use a computational model of passive avoidance learning behavior, and a multidimensional item response theory model of self-report responses to develop a joint, generative model spanning all levels of observed data. Generative modeling allowed us to estimate person-specific parameters from behavioral data that correspond to key theoretical mechanisms (i.e. reward and punishment sensitivity), and then infer relationships between these and latent externalizing and internalizing traits while accounting for measurement error that would otherwise attenuate such individual

difference correlations. We found a negative association between trait impulsivity and reward learning rate, punishment learning rate, and reward frequency sensitivity. We also identified interactions between externalizing and internalizing traits that can potentiate or protect against certain forms of impulsive and anxious behaviors and symptoms.

- Process model analysis for a gamble lottery task
    - Authors:
        - Mario Fific
        - Cara Kneeland
        - Prof. Joe Houpt
    - Abstract: There are two theoretical approaches accounting for how people preferentially choose lotteries in the classical gamble task. Following the rationality postulate, a person chooses according to the utility associated with each lottery. For example, prospect theory (PT, Kahneman & Tversky, 1979) proposes that at a final decision stage, a decision maker calculates utilities for each gamble by combining the gamble's attributes . Alternatively, following the bounded rationality postulate, a rule-based heuristic may be used to evaluate each gamble's attributes one-at-a-time (e.g. Priority Heuristic, Brandstätter, et al, 2006). This approach implies serial information processing and that a decision is made when the critical difference between compared attributes is evaluated. To validate the core assumptions of these approaches we employed a parametric version of the Systems Factorial Technology (SFT), which can be used to diagnose whether processes are organized in serial or parallel mental architectures, whether a stopping rule is exhaustive or self-terminating, and whether the processes are interdependent. Using the joint analysis of preferential choice response time distributions, we compared stochastic versions of several decision-making models: serial, parallel, parallel interactive, mixture, and the full-parameter models. The results indicated differences in how participants processed gambles' attributes. Some participants adopted either serial or parallel processing, while some relied on their trial-to-trial mixture. Some of the model fits, matched to those of the statistical full model, speaking strongly in favor of both the Take-the-Best and Weighted-Additive models. In general, these findings invite reconsiderations for heuristic-based approaches to decision making and on boundedly rational decision models

Statistical methodology

- Decisions about equivalence: A comparison of TOST, HDI-ROPE, and the Bayes factor
    - Authors:
        - Ravi Selker
        - Maximilian Linde
        - Jorge Tendeiro
        - Eric-Jan Wagenmakers
        - Don van Ravenzwaaij
    - Abstract: Some important research questions require the ability to find evidence for two conditions being practically equivalent. This is impossible to accomplish within the traditional frequentist null hypothesis significance testing framework; hence, other methodologies must be utilized. We explain and illustrate three approaches for

finding evidence for equivalence: The frequentist two one-sided tests procedure, the Bayesian highest density interval region of practical equivalence procedure, and the Bayes factor interval null procedure. We compare the classification performances of these three approaches for various plausible scenarios. The results indicate that the Bayes factor interval null approach compares favorably to the other two approaches in terms of statistical power. Critically, compared to the Bayes factor interval null procedure, the two one-sided tests and the highest density interval region of practical equivalence procedures have limited discrimination capabilities when the sample size is relatively small: specifically, in order to be practically useful, these two methods generally require over 250 cases within each condition when rather large equivalence margins of approximately 0.2 or 0.3 are used; for smaller equivalence margins even more cases are required. Because of these results, we recommend that researchers rely more on the Bayes factor interval null approach for quantifying evidence for equivalence, especially for studies that are constrained on sample size.

- Calibration in experimental psychology: designing optimal calibration experiments
    - Authors:
        - Dr. Dominik Bach
    - Abstract:Accurate measurement requires maximising the correlation between true scores and measured scores. Classical psychometric concepts such as construct validity and reliability are often difficult to apply in experimental contexts. To overcome this challenge, calibration has recently been suggested as generic framework for experimental research. In this approach, a calibration experiment is performed to impact the latent attribute in question. The a priori intended true scores can then serve as criterion, and their correlation with measured scores, termed retrodictive validity, is used to evaluate a measurement method. It has been shown that under plausible assumptions, increasing retrodictive validity is guaranteed to increase measurement accuracy. Since calibration experiments will be performed in finite samples, it is desirable to design them in a way that minimises the sample variance of retrodictive validity estimators. This is the topic of the current note. For arbitrary distributions of true and measured scores, we analytically derive the asymptotic variance of the sample estimator of retrodictive validity. We analyse qualitatively how different distribution features impact on estimator variance. Then, we numerically simulate asymptotic and finite-sample estimator variance for various distributions with combinations of feature values. We find that it is preferable to use uniformly distributed (if possible discrete) experimental treatments in calibration experiments. Secondly, inverse sigmoid systematic aberration has a large impact on estimator variance. Finally, reducing imprecision aberration decreases estimator variance in many but not all scenarios. From these findings, we derive recommendations for the design and for resource investment in calibration experiments.
- What is intentional binding measuring?
    - Authors:
        - Laura Saad
        - Julien Musolino
        - Prof. Pernille Hemmer

- Abstract: Intentional Binding (IB), the subjective underestimation of the time interval between a voluntary action and its associated outcome, is standardly regarded as an implicit measure of the sense of agency. Here, we reanalyzed results from a publicly available IB experiment (Weller et al., 2020) to evaluate three alternative explanations for their results: sequential dependencies, memory (i.e., regression to the mean), and boundary effects. The dataset contained subjective estimates of outcomes for time intervals of 100, 400, and 700ms. Aggregate results revealed overestimation for 100 and 400ms intervals and underestimation for 700ms. Controlling for sequential dependencies did not change this pattern of results. We then modeled the data using a simple Bayesian model of memory to evaluate the role of expectations over temporal intervals. Summary statistics extracted from the data were used as parameters in the model. The simulation produced a pattern of regression to the mean qualitatively similar to the observed data. Model simulations reproduced the behavioral data for the two longer time intervals, but slightly underestimated the observed overestimation at the shortest time interval. We ruled out IB as the explanation for this overestimation at the shortest time interval since the hallmark of IB is underestimation. Instead, a boundary effect likely accounts for the overestimation. In sum, the results from this dataset can be fully accounted for as manifestations of memory (i.e., regression to the mean) and a boundary effect. Crucially, no appeal to intentional binding or agency measurements of any kind are necessary.

- An integrated measure of model complexity
  - Authors:
    - J. Manuel Villarreal
    - Alexander John Etz
    - Michael Lee
  - Abstract: If two models account for data equally well, it is widely accepted that we should select the simplest one. One way to formalize this principle is through measures of model complexity that quantify the range of outcomes a model predicts. According to Roberts and Pashler (2000), however, this is only part of the story. They emphasize that a simple model is one that is falsifiable because it makes surprising predictions, which requires measuring how likely it is that data could have been observed that the model does not predict. We propose a new measure that includes both of these criteria, based on Kullback-Leibler (KL) divergence. Our measure involves the models' prior predictive distributions, which corresponds to the range of predictions they make, and a data prior, which corresponds to the range of possible observable outcomes in an experiment designed to evaluate the models. We propose that model A is simpler than model B if the KL divergence from the prior predictive distribution of model A to the data prior is greater than that of model B. This measure formalizes the idea that a model is simpler if its predictions are more surprising and more falsifiable. To demonstrate this new measure, we present a worked example involving competing models of the widely-studied memory process of free recall. The example involves a data prior based on the empirical regularity provided by the serial position curve. We show how the data prior helps measure

aspects of model complexity not captured by measuring the range of predictions made by models, and influences which model is chosen.

- Adaptive Design Optimization for the Mnemonic Similarity Task
    - Authors:
        - J. Manuel Villarreal
        - Dr. Craig Stark
        - Dr. Shauna Stark
        - Michael Lee
    - Abstract: The Mnemonic Similarity Task (MST: Stark et al., 2019) is a modified recognition memory task designed to place strong demand on pattern separation. The sensitivity and reliability of the MST make it an extremely valuable tool in clinical settings, where it has been used to identify hippocampal dysfunction associated with healthy aging, dementia, schizophrenia, depression, and other disorders. As with any test used in a clinical setting, it is especially important for the MST to be administered as efficiently as possible. We apply adaptive design optimization methods (Myung et al., 2013) to optimize the presentation of test stimuli in accordance with previous responses.This optimization is based on a novel signal-detection model of an individual's memory capabilities and decision-making processes. We demonstrate that the cognitive model is able to describe people's behavior and measure their ability to separate patterns. We also demonstrate that the adaptive design optimization approach generally significantly reduces the number of test stimuli needed to provide these measures.

Judgement

- Response time modelling reveals evidence for multiple, distinct sources of moral decision caution
    - Authors:
        - Milan Andrejević
        - Mr. Joshua White
        - Daniel Feuerriegel
        - Simon Laham
        - Stefan Bode
    - Abstract: In everyday life, moral judgments are frequently made in dynamic information environments, in which we are required to revise our first impressions after learning new information. Further, overly harsh moral judgments may damage social relationships. For these reasons, we often need to be cautious in our moral judgments, yet how caution impacts moral decision-making processes remains poorly understood. We investigated how moral valence-driven caution and contextual information expectancy-driven caution affect decision processes underlying moral judgements using the diffusion decision model (DDM) framework. Across two experiments, participants (N = 122) made moral judgements of others' sharing actions. Prior to judging, participants were informed whether contextual information regarding the deservingness of the recipient would follow. We found that participants slowed their moral judgements when judging negatively valenced actions and when expecting contextual updates. Using a hierarchical Bayesian Markov Chain Monte

Carlo estimation of the DDM, we showed that these changes can be accounted for by shifts in drift rate and decision bias (valence) and boundary setting (context), respectively. These findings demonstrate that moral decision caution can be decomposed into distinct aspects of the unfolding decision process: the widening of boundaries in response to contextual update expectancy which may serve to reduce erroneous responding in general; and decision bias shifts, which reflect additional guarding against erroneous judgements which are negative.

- Context-dependent choice and evaluation in real-world consumer behavior
    - Authors:
        - Dr. Ross Otto
        - Mx. Sean Devine
        - Dr. Aaron Bornstein
        - Dr. Kenway Louie
    - Abstract: Human information processing is naturally limited. To compensate for these limitations, humans rely on contextual information to inform their choices. A classic example of such context-dependence occurs in value-based choice: the relative value of an option depends not only on the option in question but also on the other options in the choice set, or context. While context effects of this sort have been observed primarily in small-scale laboratory studies where choice sets are tightly constrained, it is unknown whether context takes hold of choice “in the wild”. Here, we demonstrate the generality of context-dependent valuation by analyzing a massive real-world restaurant rating dataset (Yelp.com; 4.2 million ratings). We find that Yelp users make fewer ratings-maximizing choices in choice sets with higher overall average ratings. This behavior is quantitatively well-described by a divisive normalization model of choice, wherein the value of available options is scaled to the average of options in a choice set. We follow these analyses up with data from an online experiment, in which we (a) replicate the choice pattern seen in real-world Yelp users and (b) demonstrate that participants’ expectations of an option’s quality are also context dependent, in accordance with the ratings of the options the choice set, even in the absence of explicit choice. The experimental choice data was again well-characterized by a divisive normalization model of valuation. Taken together, we find compelling evidence for context-dependent valuation in behavior, manifesting both in users’ real-world and hypothetical choices and expectations.
- A rational account of the repulsion effect
    - Authors:
        - Rahul Bhui
        - Ms. Yang Xiang
    - Abstract: The attraction effect occurs when the presence of an inferior option (the decoy) increases the attractiveness of the option that dominates it (the target). Despite its prominence in behavioral science, recent evidence points to the puzzling existence of the opposite phenomenon---a repulsion effect. In this project, we formally develop and experimentally test a normative account of the repulsion effect. This theory is based on the idea that the underlying values of options are uncertain and must be inferred from the available information. A low-value decoy can signal that the target is likely of lower value as well when both are thought to be generated

by a similar process. We formalize this logic using a hierarchical Bayesian cognitive model which makes predictions about how the strength of the repulsion effect should vary with properties of the decision problem. Our theory can account for several observed phenomena linked to the repulsion effect across value-based and perceptual decision making, and we find support for its core elements in new experiments. Our results shed light on the key drivers of context-dependent judgment across multiple domains and sharpen our understanding of when decoys can be detrimental.

- Perceiving a pandemic: global-local incompatibility and COVID-19 superspreading events
    - Authors:
        - Stephen Broomell
        - Patrick Kane
    - Abstract: Superspreading events are the primary mode of infection driving the COVID-19 pandemic, but their effect on risk judgments is currently unknown. More than half a million people in the U.S. died from COVID-19 in one year, yet public risk perceptions of infection and mortality remain variable. Using a combination of epidemiological models and the psychological theory of global-local incompatibility, we theorize that superspreading diseases create a large variance in infections across geographic localities, leading to highly variable and inaccurate risk perceptions. This is problematic because these local infection rates fail to reveal the overall severity of the pandemic, which determines the personal risk of infection at any location in the near future. We test our predictions with a simulation study and a nationally representative study of U.S. citizens (N=3956) conducted in April 2020. Supporting our theory, we find that localized county-level infection rates of COVID-19 are unreliable predictors of national infection rates. However, they explain a significant proportion of variance in judgments of national infection rates, contributing to judgment errors. These results support our theoretical approach for modeling this unique judgment context as an incompatibility between global and local information, providing a framework to predict how citizens will react to novel large scale (global) risks. Our results also help explain the extreme polarization witnessed in the U.S. regarding perceptions of the risks of the COVID-19 pandemic. Accounting for the variability of local experiences with a pandemic can help future generations prepare for how to respond to similar threats more effectively.
- A model of decision making under alcohol intoxication
    - Authors:
        - Sara McMullin
        - Denis McCarthy
        - Prof. Clintin Davis-Stober
    - Abstract: We present a new model of decision making under alcohol intoxication. The scope of the model covers binary choice, where choice alternatives are allowed to have any (finite) number of attributes. The acute effects of alcohol intoxication on decision making are accounted for by two parameters, one governing increased choice inconsistency due to “noisier" cognitive representations of the choice attributes, the other governing how attention to choice attributes changes, accounting

for the well-known alcohol myopia effect. We demonstrate how our model can account for a variety of alcohol impaired decisions across many different contexts (e.g., decisions to drink and drive, sexual decisions) and be applied using various methodological approaches (e.g., cognitive neuroscience, ecological momentary assessment). We show that our model contains a standard model of multi-attribute decision making, the probit random utility model, as a special case when the alcohol-impairment parameters are set equal to values corresponding to no alcohol impairment.

- Modeling preference reversals between intertemporal choice and pricing
    - Authors:
        - Peter Kvam
        - Ms. Konstantina Sokratous
    - Abstract: Preference reversals in risky choice -- where people select low-risk over high-risk prospects in binary choice but assign higher prices to high-risk than low-risk prospects -- have suggested that the valuation processes underlying pricing are distinct from those underlying choice. Despite this, theories of intertemporal choice typically do not distinguish between response processes for pricing and choice, assuming instead that eliciting either response will lead to the same inferences about people's preferences for delayed outcomes. We show that this assumption is incorrect, and develop a dynamic model of pricing that can account for preference reversals in intertemporal choice. Across two studies, participants showed a preference for smaller sooner options in choice but larger later ones when pricing potential gains (Experiment 1) and losses. This reversal in pricing results in less impulsive behavior, suggesting that pricing frames may reduce choice impulsivity. To explain these diverging price and choice findings in a common framework, we propose a variant of a dynamic price accumulation model that we previously developed to model risky choice. This model is able to predict preference reversals using a common set of parameters for choice and pricing (joint model), providing an account of both response types while extending its account of preference reversals to delayed outcomes.

Estimation

- Evaluating parameter recovery of subject level parameters in the memory measurement model framework
    - Authors:
        - Jan Göttmann
        - Dr. Gidon Frischkorn
        - Anna-Lena Schubert
        - Klaus Oberauer
    - Abstract: The memory measurement model (M3; Oberauer & Lewandowsky, 2018) is a cognitive measurement model designed to isolate parameters associated with different processes in working memory. It assumes that different categories of representations in working memory get activated through distinct processes. Transforming the activation of the different item categories into their respective recall probabilities then allows to estimate the contributions of different memory processes to working memory performance. So far, parameter recovery was assessed only for

group level parameters of the M3. In contrast to experimental research, individual differences research relies on variation in subject parameters. The quality of parameter recovery of subject parameters has, however, not yet been investigated. To analyze parameter recovery of subject parameters of the M3, we ran a parameter recovery simulation to assess the model performance in recovering subject-level parameters dependent on different experimental conditions. In this talk, we will present the results of this parameter recovery study that used a multivariate parametrization of the model implemented in STAN using the no-u-turn sampler (Hoffman & Gelman, 2011). The results of the simulation indicate that our implementation of the M3 recovers subject parameters acceptably. Based on differences between experimental conditions, we will provide recommendations for using the M3 in individual differences research. Altogether, our parameter recovery study showed that the M3 is easily scalable to different experimental paradigms with sufficient recovery performance.

- Another approximation of the first-passage time densities for the Ratcliff diffusion decision model
    - Authors:
        - Mr. Kendal Foster
        - Dr. Henrik Singmann
    - Abstract: The Ratcliff 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 (PDF) contains an infinite sum for which several different approximations exist. We present a novel method for approximating this PDF, implemented in C++ but using the R package Rcpp to provide an R language interface to the faster C++ language. In addition to our novel approximation method, we also compiled all known approximation methods for the PDF (with fixed and variable drift rate), including previously unused combinations of techniques found in the relevant literature. We ported these approximation methods to C++ and optimized them to run in this new language. Given an acceptable error tolerance in the value of the PDF approximation, we benchmarked all of these approximation methods to compare their speed against each other and also against commonly used R functions from the literature. The results of these tests show that our novel approximation method is not only orders of magnitude faster than the current standards, but it is also faster than all of the other approximation methods available even after translation and optimization to the faster C++ language. All of these approximation methods are bundled in the R package fddm; this package is available via CRAN, and the source code is available on GitHub.
- Parameter agreement and sources of disagreement across the Bayesian and frequentist MPT multiverse
    - Authors:
        - Dr. Henrik Singmann
        - Prof. Beatrice Kuhlmann
        - Dr. Julia Groß
    - Abstract: Cognitive modelling results should be robust across reasonable data-analysis decisions. For parameter estimation, two essential decisions concern the

aggregation of data (e.g., complete pooling or partial pooling) and the statistical framework (frequentist or Bayesian). The combination of these decision options spans a multiverse of estimation methods. We analysed a) the magnitude and b) possible sources of divergence between different parameter estimation methods for nine popular multinomial processing tree (MPT) models (e.g., source monitoring, implicit attitudes, hindsight bias). We synthesized data from 13,956 participants (from 142 published studies), and examined divergence in core model parameters between nine estimation methods that adopt different levels of pooling within different statistical frameworks. Divergence was partly explained by uncertainty in parameter estimation (larger standard error = larger divergence), the value of the parameter estimate (parameter estimate bear the boundary = larger divergence), and structural dependencies between parameters (larger maximal parameter trade-off = larger divergence). Notably, divergence was not explained by participant heterogeneity - a result that is unexpected given the previous emphasis on heterogeneity when choosing particular estimation methods over others. Instead, our synthesis suggests that other, idiosyncratic aspects of the MPT models also play a role. To increase transparency of MPT modelling results, we propose to adopt a multiverse approach.

- Errors-in-variables regression analysis to investigate unconscious mental processes
    - Authors:
        - Simone Malejka
        - Miguel A. Vadillo
        - Zoltán Dienes
        - David R. Shanks
    - Abstract: A large number of researchers agree that people can detect regularities in their environment and adapt behavior accordingly in the absence of awareness. The presumed unconscious effect of stimuli, contingencies, or rules on learning has been shown in a variety of paradigms (e.g., repetition priming, contextual cueing, unconscious conditioning, artificial grammar learning). Evidence that learning was indeed unconscious sometimes requires accepting the null hypothesis that participants were unaware of the regularities (indirect-without-direct-effect data pattern). As null-hypothesis significance testing is a poor method for proving the absence of an effect, one can regress the learning measure on the awareness measure, so that a significant intercept would be understood as successful learning without awareness (Greenwald, Klinger, & Schuh, 1995). However, the relationship between predictor and criterion variable is frequently biased by their respective low reliabilities. In particular, ignoring measurement error in the predictor variable will disattenuated the regression slope towards zero, which in turn could raise a true zero intercept above zero. As a solution, Klauer, Draine, and Greenwald (1998) suggested a correction method for predictor variables with rational zero points (such as d') in the framework of errors-in-variables regression. In a series of simulations, we show that their method still overestimates true zero intercepts. As an alternative, we suggest that researchers (a) use a generative Bayesian regression approach that takes the uncertainty of predictor and criterion variable into account and (b) calculate Bayes factors to test the crucial intercept.

- PyBEAM: A Bayesian approach to parameter inference for a wide class of binary evidence accumulation models.
    - Authors:
        - Matt Murrow
        - Dr. Bill Holmes
    - Abstract: Many decision-making theories are encoded in a class of processes known as evidence accumulation models (EAM). These assume that noisy evidence stochastically accumulates until a set threshold is reached, triggering a decision. One of the most successful and widely used of this class is the drift-diffusion model (DDM). The DDM however is limited in scope and does not account for processes such as evidence leakage, changes of evidence, or time varying caution. More complex EAMs can encode a wider array of hypotheses, but are currently limited by the computational challenges. In this work, we develop the python package PyBEAM (Bayesian Evidence Accumulation Models) to fill this gap. Toward this end, we develop a general probabilistic framework for predicting the choice and response time distributions for a general class of binary decision models. In addition, we have heavily computationally optimized this modeling process and integrated it with PyMC3, a widely used python package for Bayesian parameter estimation. This 1) substantially expands the class of EAM models to which Bayesian methods can be applied, 2) reduces the computational time to do so, and 3) lowers the entry fee for working with these models. I will demonstrate the concepts behind this methodology, its application to parameter recovery for a variety of models, and apply it to a recently published data set to demonstrate its practical use.

Formal analysis

- A representation theorem for finite best-worst random utility models
    - Authors:
        - Hans Colonius
    - Abstract: Choosing an element from an offered set of alternatives is arguably the most basic paradigm of preference behavior. Typically, if the same set is offered several times, the choice will not always be the same. This is often attributed to the participant's preference fluctuating over time due to the effect of various alternatives to be compared, or to the difficulty of distinguishing between similar alternatives.Theories of best-choice behavior try to account for the probability of choosing an alternative y from an offered set Y, a subset of base set X. This intrinsic randomness leads naturally to postulating the existence of a random variable U(x) , for each alternative x in Y, representing the momentary strength of preference for alternative x. Alternative y chosen from Y if the momentary (sampled) value of U(y) exceeds that of any other alternative, aka random utility model (RUM). Falmagne (1978) showed that nonnegativity of certain linear combinations of choice probabilities (Block-Marschak polynomials) is necessary and sufficient for the existence of a RUM representation of best-choice probabilities. Marley & Louviere (2005) proposed an alternative task, where a participant is asked to select both the best and the worst option in the available subset of options Y. Let B(b,w,Y) be the probability that a participant chooses b as best and w as worst alternative in the set Y. Here I show that non-negativity of best-worst Block-Marschak polynomials,

appropriately defined, is necessary and sufficient for the existence of a RUM representation of best-worst choice probabilities. The theorem is obtained by extending proof techniques for the corresponding result on best choices (Falmagne, 1978).

- Measures of the degree of contextuality and noncontextuality
    - Authors:
        - Dr. Ehtibar N. Dzhafarov
        - Dr. Janne Kujala
        - Víctor Hernando Cervantes Botero
    - Abstract: Many if not all objects of research, be it in psychology, quantum physics, computer science, etc., can be presented by systems of random variables, in which each variable is identified by what it measures (what question it answers) and by contexts, the conditions under which it is recorded. Systems can be contextual and non contextual, contextuality meaning that contexts force random variables answering the same question to be more dissimilar than they are in isolation. There is a consensus that it is useful to measure degree of contextuality when a system is contextual. Measures of noncontextuality, however, have not been proposed until very recently. We will outline a theory of contextuality measures and noncontextuality measures applied to an important class of systems, called cyclic. Using the example of a cyclic system of rank 2 (the smallest nontrivial system formalizing, e.g., the question order effects in psychology), we explain why measures of noncontextuality are as important as measures of contextuality. Literature: Dzhafarov, E.N., Kujala, J.V., & Cervantes, V.H. (2020). Contextuality and noncontextuality measures and generalized Bell inequalities for cyclic systems. Physical Review A 101:042119. (available as arXiv:1907.03328.) Erratum Note: Physical Review A 101:069902.
- Extending Knowledge Space Theory to contingent information with bitstring semantics
    - Authors:
        - Mr. Wai Wong
        - Prof. Joost Vennekens
        - Prof. Walter Schaeken
        - Prof. Lorenz Demey
    - Abstract: There is a great similarity in the knowledge modelling process between education and knowledge engineering. In education, psychometrician and educator work together to assess students' knowledge states and what they are ready to learn next. Knowledge Space Theory (KST) maps out the knowledge structure of different concepts that a student can learn and the dependencies among these concepts. Meanwhile in knowledge engineering, knowledge engineer and domain expert work together to extract business knowledge so that they can automate decisions according to the client's situation. Common business knowledge representation standards such as Decision Model and Notation (DMN) provide the industry with a modelling notation that supports decision management. The similarity of the collaborations among stakeholders in the knowledge extraction process motivates us to investigate the possibility of applying KST in the industrial setting. However, KST lacks the ability to model the learning of contingent information, such as learning whether or not a given client speaks English (e.g., to determine if a translator is

needed). If one learns that a particular client does in fact speak English, it becomes impossible to later learn that this same client does not speak English. This violates KST's assumption that knowledge is always cumulative. We propose as a solution to use bitstring semantics to represent the contingent knowledge. Bitstring semantics is a recent logical formalism exploring the meaning relations between different expressions. In this talk, we will illustrate how we can extend previous work on KST with bitstring semantics to construct contingent knowledge structures.

- A hierarchical approach to measuring contextuality
    - Authors:
        - Víctor Hernando Cervantes Botero
        - Dr. Ehtibar N. Dzhafarov
    - Abstract: Many systems in which contextuality is studied have in common that their (non)contextuality is determined by particular configurations of pairwise correlations. Such systems are used to describe the question order effect in psychology, the Einstein-Podolsky-Rosen-Bohm paradigm in quantum physics, and many other situations. The prominence of pairwise correlations leads one to the incorrect intuitive idea that all contextuality appears on the level of pairwise associations, perhaps even only within cyclic subsystems. We present a new, hierarchical measure of (non)contextuality in which contextuality may arise at the level of pairwise, triple, quadruple, etc. associations of random variables. This measure allows one to look at (non)contextuality as varying not only in degree but also in pattern.
- Revisiting the connection between the Luce's choice rule and signal detection theory
    - Authors:
        - Maria Robinson
        - Prof. Timothy Brady
        - Edward Vul
        - Isabella DeStefano
    - Abstract: In many decision tasks, we have a set of alternative choices and are faced with the problem of how to take our latent preferences or beliefs about each alternative and make a single choice. For example, we must decide which item is 'old' in a forced-choice memory study; or which cereal we prefer in a supermarket; or which color a word is in a Stroop task. Modeling how people go from latent strengths for each alternative to a single choice is thus a critical component of nearly all cognitive and decision models. Most models follow one of two traditions to establish this link. Modern psychophysics and memory researchers make use of signal detection theory, in the tradition of Fechner (1860) and Thurstone (1929), assuming that latent strengths are perturbed by noise, and the highest resulting signal is selected (e.g., Wixted, 2020). By contrast, many modern cognitive modeling and machine learning approaches use the softmax rule to give some weight to non-maximal-strength alternatives (Luce choice axiom; Luce, 1959). Despite the prominence of these two theories of choice, current approaches rarely address the connection between them, and the choice of one or the other appears more motivated by the tradition in the relevant literature than by theoretical or empirical reasons to prefer one theory to the other. The goal of the current work is to revisit this topic by elucidating which of these two models provides a better characterization

of latent processes in K-alternative decision tasks, with a particular focus on memory tasks. In line with previous work (e.g., Luce and Suppes, 1966; Yellot, 1977), we find via both simulation and mathematical proofs that the softmax and signal detection link functions can mimic each other with high fidelity in all circumstances. However, we show that while the softmax parameter varies across task structures using the same stimuli (i.e., changes when K is varied), the parameter d' of the signal-detection model is stable. The results of these studies are consistent with the results of Treisman and Faulkner (1985) in a novel suite of memory tasks. Together, our findings indicate that replacing softmax with signal-detection link models would yield more generalizable predictions across changes in task. More ambitiously, the invariance of signal detection model parameters across different tasks suggests that the mechanisms of these models (i.e., the corruption of signals by stochastic noise) may be more than just a mathematical convenience but reflect something real about human decision-making.

- Advances in Valence-Weighted Distance: merging probability weighting with the Sharma-Mittal family of entropies
    - Authors:
        - Mikaela Akrenius
    - Abstract: Akrenius (2020) proposed a novel probability weighting function, Valence-Weighted Distance (VWD), which builds on the notion that a reduction in uncertainty carries psychological utility. VWD presumes that a probability is evaluated relative to a plausible expectation (uniformity), and that the perceived distance between the probability and uniformity is influenced by the entropy of the distribution that the probability is embedded in. VWD reproduces the characteristic shape of existing probability weighting functions, makes novel predictions, and provides a parsimonious explanation for findings in probability and frequency estimation related tasks. To account for individual differences, VWD can be complemented with the Sharma-Mittal (1975) family of entropies, which has previously been applied in models of information search and hypothesis testing (Crupi et al., 2018). I review the theory underlying VWD, introduce its extension with the Sharma-Mittal family, and present some of the theoretical and empirical implications that follow.

Time series

- Explaining task-switching behavior using evidence accumulation models
    - Authors:
        - Lori Mahoney
        - Prof. Joe Houpt
        - Ion Juvina
    - Abstract: Performing a complex task provides opportunities to switch between multiple subtasks, where the individual decides between remaining on the current task or selecting an alternate task, with large variation in individual behavior. Information foraging theory states that people adapt their strategies to maximize the amount of information gained per unit time, leading them to either exploit existing information or switch tasks and explore to gather more information. Evidence accumulation models provide additional insight into the cognitive mechanisms of decision making; for task-switching decisions, the speed of information processing

describes the attractiveness of the alternate task, while the response threshold describes the inhibition to leave the ongoing task. This research uses two versions of the linear ballistic accumulator (LBA) to investigate task-switching decisions. We apply an existing multi-attribute, multi-alternative LBA, based on cumulative prospect theory, by assuming that exploitation corresponds to being risk adverse and exploration corresponds to risk seeking, to define attribute-level subjective values and weighting functions that capture an individual's pre-decision task preference. We develop an alternate version, using expected gain from information processing theory, that explains subjective value and attention weight at the alternative-level to determine drift rates for the LBA model. We compare the two versions of the model to determine, using data previously collected during a complex task, if individuals base their task preference on individual task attributes or the overall gain provided by the task. We also compare response threshold results to the switch-avoidance tendency identified in a well-known task-switching model.

- Cognitive models of sequential choice in the optimal stopping task
    - Authors:
        - Erin Bugbee
        - Chase McDonald
        - Erin N McCormick
        - Joshua Fiechter
        - Christian Lebiere
        - Dr. Leslie Blaha
        - Cleotilde (Coty) Gonzalez
    - Abstract: In the optimal stopping problem, a decision maker aims to select the option that maximizes reward in a sequence, under the condition that they must select it at the time of presentation. Past literature suggests that people use a series of thresholds to make decisions (Lee, 2006), and researchers have developed a hierarchical Bayesian model, Bias-From-Optimal (BFO), to characterize these thresholds (Guan et al., 2015, 2020). BFO relies on optimal thresholds and the idea that people's thresholds are characterized by how far they are from optimal and how this bias increases or decreases throughout the sequence. In this work, we challenge the assumption that people use thresholds to make decisions. We develop a cognitive model based on Instance-Based Learning Theory (Gonzalez et al., 2003) to demonstrate an inductive process by which individual thresholds are derived, without assuming that people use thresholds or relying on optimal thresholds. The IBL model makes decisions by considering the current value and the distance of its position from the end of the sequence, and learns through feedback from past decisions. Using this model, we simulate the choices of 56 individuals and compare these simulations with empirical data provided by Guan et al. (2020). Our results demonstrate that the IBL model replicates human behavior and generates the BFO model's thresholds, without assuming any thresholds. Overall, our approach improves upon previous methods by producing cognitively plausible choices, resembling those of humans. The IBL model can therefore be used to predict human risk tendencies in sequential choice tasks.

- Mixing process and descriptive runners in the race model of response inhibition: a hybrid approach to the stop-signal paradigm
    - Authors:
        - Charlotte Coosje Tanis
        - Andrew Heathcote
        - Mr. Mark Zrubka
        - Dr. Dora Matzke
    - Abstract: Response inhibition is frequently measured using the stop-signal paradigm, where responses must be withheld when a “stop” signal appears. This paradigm assumes that go and stop stimuli trigger competing runners. The first runner crossing a boundary wins, and determines whether a response is performed. A tension exists between two categories of models: descriptive and process models. Descriptive models define the speed of the runners, whereas process models express the latency of going (go RT) and stopping (stop-signal RT) in terms of psychological mechanisms and explain how their distributions emerge. One drawback of the process approach is an inability to recover data-generating parameters and thereby not qualifying as a measurement model. In contrast, the descriptive BEESTS approach recovers these parameters, but the psychological interpretation of its parameters is ambiguous which hampers the understanding of RT differences between groups or manipulations. We propose to mix a process “evidence-accumulation” account of the go runners and a descriptive approach of the stop runner. To instantiate this hybrid approach, we assumed Wald distributions for the finishing times of the go runners and, similar to BEESTS, an ex-Gaussian distribution for the stop runner. This approach results in a practically useful measurement model, with good parameter recovery by Bayesian hierarchical methods in realistic designs. By mixing racers, we garner advantages of both process and descriptive models: all parameters are interpretable in a measurement sense, parameters describing go runners are interpretable psychologically, and the stop parameters can be used to reliably and validly estimate stop-signal RTs.
- Quantifying sources of within-subject variance across different behavioural tasks
    - Authors:
        - Dr. Marlou Perquin
        - Prof. Tobias Heed
        - Prof. Christoph Kayser
    - Abstract: Reaction time (RT) series from any behavioural task show large fluctuations from trial to trial. These fluctuations are characterised by temporal trends such as positive autocorrelations between subsequent trials. In typical experimental paradigms, the trial-to-trial fluctuations are ignored, and RTs are summarised into conditional means, which are then statistically compared on the group level. However, at the level of individual participants, it often remains unknown which part of the total trial-to-trial variance is driven by the conditional manipulations. In the current study, we quantified sources of within-participant variance in RT across archival datasets. Specifically, we determined the relative contributions of experimental manipulations and sequential effects, split into trial-by-trial autocorrelations and blockwise trends. We quantified the trial-to-trial variance of RT

with general linear models on the individual participant data. Results from 16 datasets (N = 1474) from perceptual and cognitive control tasks show that the conditional, autocorrelative, and blockwise trend factors explained similar amounts of variance in trial-to-trial RTs. Furthermore, we examined individual differences in explained variance with between-subject correlations between the amount of explained variance and performance. RT variability correlated positively with the amount of variance explained by the conditional and block wise trend factors, but negatively with variance explained by the autocorrelation factors. Overall, experimental conditions only explained a small proportion of the total variance, and large parts of individual trial-by-trial variance remained unexplained by the investigated factors.

- A model of timing in simple anticipatory decisions
    - Authors:
        - Ms. Konstantina Sokratous
        - Peter Kvam
        - Guy Hawkins
    - Abstract:Response time models are typically applied to make predictions about when participants will react to a stimulus. However, many of the choices we make require us to proactively plan when to act: when to leave home to arrive somewhere on time, when to swing at a ball to hit it (tennis, baseball, cricket), and so on. These anticipatory responses can also be modeled as an evidence accumulation process, where we form joint expectations of both object and time. To understand these dynamic representations, participants were asked to make decisions about two anticipated events. In an initial experiment, they were asked to decide when a moving, partially occluded ball will hit a wall. In a second experiment, participants were asked to infer the ball's position at a particular time after it became occluded behind the wall. We manipulated the speed at which the ball travels, its distance from the wall, and the time for which the ball is occluded, forcing the decision-maker to mentally represent and calculate the object's dynamic position and motion as they form judgements about eventual locations or timing. We model response times using the extended Wald accumulator model to draw parallels between the changes in speed, distance, and length with the corresponding changes in the model's parameters: drift, threshold, and non-decision time. The results from both tasks suggest that response times in anticipatory decisions are right-skewed -- mostly too slow -- and the estimated parameters of the Wald model successfully predicted individual response times by condition.
- Evidence accumulation or reinforcement learning? Modeling sequential decision-making in the "observe or bet" task
    - Authors:
        - Dr. Beth Baribault
        - Ms. Manon Ironside
        - Dr. Sheri Johnson
        - Anne Collins
    - Abstract: How do we decide whether we should explore or exploit in uncertain environments where feedback is intermittent? In this talk, we compare two

approaches to computational modeling of the cognitive process underlying such decisions, using control group data from an ongoing clinical research collaboration. Participants completed multiple blocks of the “observe or bet” task, which is a dynamic sequential decision-making task. To maximize reward, participants must strike a balance between betting on (but not seeing) which event will occur, versus observing events in the sequence (and forgoing gaining or losing points). Participants efficiently alternated between observing and betting, while overall observing more at the start of a sequence, and betting more towards the end. To better understand this data, we used two classes of hierarchical Bayesian models. First, we implemented nine versions of the “heuristic model” of this task, developed by Navarro, Newell, & Schulze (2016), which posits a cross-trial evidence accumulation process. Second, we implemented eight variants of a modified reinforcement learning (RL) model, which is a novel adaptation of Q-learning. Across all models, the modified RL model with counterfactual learning and a high fixed value of observing provided the best fit to the observed data. We discuss implications for modeling of this task, and for RL modeling more generally. We emphasize how this challenges a strict conceptualization of RL, as the modified RL model’s success suggests that the same computations responsible for learning from rewards might also subserve learning from outcomes that are non-extrinsically (but potentially intrinsically) rewarding.

Measurement

- A model-based examination of scale effects in student evaluations of teaching
    - Authors:
        - Karyssa Courey
        - Michael Lee
    - Abstract: Student evaluations of teaching are widely used to assess instructors and courses. Using a model-based approach and Bayesian methods, we examine how the direction of the scale, labels on scales, and the number of options impact ratings. We conduct a within-participants experiment in which respondents evaluate instructors and lectures using different scales. We find people tend to give positive ratings, especially when using letter scales compared to number scales. Furthermore, people tend to use the end-points less often when a scale is presented in reverse. Our model-based analysis allows us to infer how the features of scales shift responses to higher or lower ratings and how they compress scale use to make end-point responses more or less likely. The model also makes predictions about equivalent ratings across scales, which we demonstrate using real-world evaluation data. Our study has implications for the design of scales and for their use in assessment.
- A hierarchical Bayesian model of the continuous performance task
    - Authors:
        - Ms. Yiyang Chen
        - Nicholas Breitborde
        - Mario Peruggia
        - Trisha Van Zandt
    - Abstract: The continuous performance task (CPT) is widely used to assess deficits in sustained attention among people with psychotic disorders. People with psychotic

disorders have poorer performance in the CPT compared to individuals without psychosis, but it is not exactly clear what specific factors may contribute to these between-group differences in sustained attention. To investigate the factors that may contribute to deficits in sustained attention among individuals with psychotic disorders, we propose a theory-based hierarchical Bayesian model for the CPT, and apply this model to a data set comprised of people with and without first-episode psychosis. This model allows us to find the potential underlying mechanism for people's performance deficits on the CPT by interpreting changes in the model's estimated parameters. Application of this model to the data set reveals that people with first-episode psychosis might have more difficulty identifying the mismatches between stimuli, and utilizing this mismatch information to guide their behaviors.

- Measuring event-order memory with a ranking task
    - Authors:
        - Dr. Richard Chechile
        - Giulia Pintea
    - Abstract: The ranking procedure requires participants to rank the entries on a line-up memory test where there is a single old item and n-1 novel foils; the ranking is from the perceived most likely target (with a rank of 1) to the least likely target (with a rank of n). This assessment procedure results in a critical test for the two-high threshold model (Chechile & Dunn, 2021). Moreover, ranking data can readily be used to construct a hazard function, which can be useful for assessing any model of recognition memory. In the current paper, the ranking procedure is employed to examine the memory of order. After the presentation of a series of items for study, a random triplet of these items is tested to assess the memory of the relative order of the items. Chechile and Pintea (2021) previously developed an Event Order (EO) model for measuring four states of triplet order. They also provided evidence that order knowledge is a separate attribute of memory from item content. Chechile and Pintea (2021) estimated the four-states of order knowledge from data obtained that used a series of forced-choice tests. In the current paper, it is shown that the ranking procedure can be also used to estimate the parameters of the EO model. The ranking test method also provides a way to generate an empirical hazard function for memory order, which can be useful for comparing rival models of memory order.
- A computational model of the IEDS task helps shed light on attention shifting in clinical groups
    - Authors:
        - Dr. James Yearsley
    - Abstract: The Intra-Extra-dimensional set shift task (IEDS) is a widely used test of learning and attention, believed to be sensitive to aspects of executive function. The task proceeds through a number of stages, and it is generally claimed that patterns of errors across stages can be used to discriminate between reduced attention switching and more general reductions in rates of learning. A number of papers have used the IEDS task to argue for specific attention shifting difficulties in Autism Spectrum Disorder (ASD) and Schizophrenia, however, it remains unclear how well the IEDS really differentiates between reduced attention shifting and other causes of impaired performance. To address this issue, we introduce a simple computational

model of performance in the IEDS task, designed to separate the competing effects of attention shifting and general learning rate. We fit the model to data from ASD and comparison individuals matched on age and IQ, as well as to data from four previous studies which used the IEDS task, using a combination of MCMC and Approximate Bayesian Computation techniques. Model fits do not show consistent evidence for reductions in attention shifting rates in ASD and Schizophrenia. Instead, we find performance is better explained by differences in learning rate, particularly from punishment, which we show correlates with IQ. We, therefore, argue that the IEDS task is not a good measure of attention shifting in clinical group.

- Comparing eyewitness identification procedures with information-theory measures
    - Authors:
        - Jeffrey Starns
        - Andrew Cohen
        - Caren Rotello
    - Abstract: Eyewitness identifications play a key role in many criminal investigations. Investigators have a wide range of options for how they conduct an identification attempt, and eyewitness researchers have explored many of the relevant variables, such as whether a suspect is shown to a witness individually (a “showup”) or together with a number of fillers (a “lineup”). Unfortunately, different measures of lineup effectiveness often support different research conclusions and policy recommendations. We show that existing measures are incomplete in the sense that they do not use all of the information from the reference population defining witness performance. We introduce a complete measure, Expected Information Gain (EIG), by applying information-theory principles to identification data. EIG identifies the procedure that produces the most information about suspect guilt or innocence across all of the possible witness responses. Thus, EIG is a useful measure for policy-focused research.

**Hypergeometric room**

Flexible cognitive architectures for response inhuntion ~Estes award address by Dora Matzke

- Flexible cognitive architectures for response inhibition
    - Authors:
        - Dr. Dora Matzke
    - Abstract: Imagine you driving down the highway stuck behind a slow car. You glance in the rear-view mirror to check if it is safe to overtake, but before you do so, you hear the siren of an ambulance and abort the overtaking manoeuvre. This type of response inhibition—the ability to stop ongoing responses that have become no longer appropriate—is a central component of executive control and is essential for safe and effective interaction with an ever-changing and often unpredictable world. Inhibitory ability is typically quantified by the stop-signal reaction time, the completion time of an inhibitory process triggered by a signal to stop responding. Because stop-signal reaction times cannot be directly observed, they must be inferred based on a model in which independent inhibitory (“stop”') and response (“go”) processes race with each other to control behavior. I review the limitations of the traditional non-parametric race model framework and show that it cannot be used to investigate

response inhibition in the full range of situations and paradigms that are relevant to the study of cognitive control. To address this shortcoming, I outline a flexible parametric approach that generalizes the race model to account for aspects of behavior that are characteristics of real-world stopping, such as choice errors, attentional lapses, and the interaction between the stop and go processes. I propose various parametrizations of the framework, ranging from the descriptive ex-Gaussian distribution to a racing diffusion evidence-accumulation architecture, explore the strengths and weaknesses of the different models, and illustrate their utility with clinical and experimental data in choice-based as well as anticipated-response-based paradigms. I end with discussing the potential of this modeling framework to provide a comprehensive account of the mental processes governing behavior in realistically complex situations, and how it may contribute to the prediction of stopping performance in dynamic settings.

Time impacts decision processes in many ways ~Estes award address bby Guy Hawkins

- Time impacts decision processes in many ways
    - Authors:
        - Guy Hawkins
    - Abstract: Decision making capabilities have outcomes of great significance for individuals and groups. Yet, decision processes and outcomes are robustly affected by a range of contextual factors, which can influence even the best decision makers. One reliable contextual factor is time. Through the lens of experimental studies and computational modelling, this presentation provides illustrative case studies of the different ways in which time impacts decision making behaviour. It will cover decision making at different scales - from individual decisions, to collective sets of decisions, through to natural variation in decisions over time. In each case, psychological theory is developed to provide a deeper explanation of the latent processes people use to make decisions, and in turn how those processes are adapted when faced with different temporal contexts and pressures.

Three questions about mathematical psychology ~ Keynotes address by Colin Allen

- Three questions about mathematical psychology
    - Authors:
        - Prof. Colin Allen
        - Mr. Brendan Fleig-Goldstein
        - Ms. Mara McGuire
        - Mr. Nuhu Osman Attah
        - Ms. Dzintra Ullis
    - Abstract: We are investigating the intellectual roots of mathematical psychology and its relationships to adjacent areas such as psychophysics, cognitive science, computational neuroscience, and formal measurement theory. Our approach is one of integrated history and philosophy of science, meaning that we seek not just to answer questions about the past, but use this history to gain clarity on outstanding philosophical issues for the field and in psychology and science more generally. To help situate mathematical psychology we are gathering primary sources and secondary materials, such as histories and textbooks, that help us to contextualize it within the much longer arc that begins with the emergence of scientific psychology in

the 19th Century (recently covered historically by Murray & Link, 2021). We have begun to trace out the lineages of some key early figures, and started to interview those who are still alive, their students, and other active researchers about their conceptions of the field, motivations for identifying with it, and aspirations for its future. This preliminary work has helped to identify three related questions that we believe are central to understanding mathematical psychology. 1. What (if anything) makes its use of mathematics reasonably effective? This question explicitly echoes physicist Eugene Wigner's widely-read paper "The unreasonable effectiveness of mathematics in the natural sciences." It prompts us to address how mathematical psychology arose in the context of the use of mathematics in other sciences. Our interviews have already uncovered interesting points of contrast between mathematical psychology and work in other areas, such as the physics-inspired mathematical biology of Nicolas Rashevsky, the symbolic computational cognitive science of Herbert Simon, and connectionism. We have also heard contrasting views on the significance of the foundational work on measurement theory by Krantz, Luce, Suppes, and Tversky. 2. What makes its use of mathematics different from other branches of psychology? Navarro (2021) has recently argued that "If mathematical psychology did not exist we might have to invent it" but what contrasts between mathematical psychology and other subfields of psychology make this true? Here we are interested in the relationship of mathematical psychology to contemporaneous subfields such as psychophysics and psychometrics, as well as to nearby areas of cognitive science. In interviews we have already been told of the importance placed by early mathematical psychologists on constructing models responsive to experimental data. We seek to understand the other objectives constraining the types of models favored by mathematical psychologists. 3. How should we think about mathematical psychology in relation to cognitive science? In our interviews already we have learned about differences of opinion concerning the strategy of aligning mathematical psychology with cognitive science. Tracing the academic heritage of key figures such as Estes also reveals their proximity to animal learning and behaviorism, suggesting a possible source of skepticism about cognitive science. Interviewees have also stressed the importance of having access to powerful computers in the early days of mathematical psychology. Their use of computers to process relatively large amounts of experimental data stands in contrast to the inspiration computers have provided to the "computationalist" theory of mind which serves as a central dogma of many cognitive scientists. In future work we pursue questions about the interplay between mathematical psychology and cognitive neuroscience, as well as contrasts to rational-analysis approaches such as Bayesian cognitive science. We do not expect to find consensus among mathematical psychologists on the answers to these questions. But we intend that our investigation will help provide a roadmap to the field, past, present and future. In presenting this work at what is still a preliminary stage, we thus hope to engage MathPsych attendees not just in looking backwards, but in contributing to understanding the philosophical foundations of mathematical psychology in a way that can perhaps help shape its future.

Senior Fellow Award 2021~ Fireside chat with James T. Townsend

- A conversation with the 2021 Senior Fellow Award winner on their contributions and history
    - Authors:
        - Prof. Clintin Davis-Stober
        - James T. Townsend
        - Joachim Vandekerckhove
    - Abstract:
        - Prof. James T. Townsend is the 2021 Senior Fellow Award winner for the Society for Mathematical Psychology. This award is intended to honor a lifetime of scientific contribution to the field. We present an interview with Prof. Townsend, in which he discusses his career, scientific contributions, and current research with Clintin Davis-Stober. We hope you enjoy it.

Knowledge representation and retrieval ~ Estes award address by Joseph Austerweil

- Knowledge representation and retrieval
    - Authors:
        - Prof. Joe Austerweil
    - Abstract: In this talk, I focus on one facet of my research program: knowledge retrieval. I formulate, describe, and extend a novel model that retrieves items by randomly following associations between items in memory. I show how this model can capture patterns in how people retrieve items from a category, patterns that previously were used to argue that memory search must be guided by a strategic, rather than a random process. Further, I show that for a random search over knowledge to capture human memory retrieval, knowledge must be represented in a structured manner (e.g., network), and that a spatial representation is insufficient. Extending the new model, I develop and empirically validate a novel machine learning method for estimating network representations of groups and individuals efficiently. I then apply this method to reveal differences between the knowledge representations of older individuals that are cognitively impaired and matched controls. I will conclude with a discussion of an in progress project, which examines healthy and unhealthy cognitive aging using a low-cost, naturalistic micro longitudinal design.

**Logistic room**

Women of mathematical psychology roundtable

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Women of mathematical psychology women-only roundtable

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ICCM business meeting

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Women of Mathematical psychology roundtable

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Society for mathematical psychology business meeting

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**Multinomial room**

28th ACT-R workshop ~ Social cognition (Start:11:00 EDT Jul 12, 2021 End:12:20 EDT Jul 12, 2021)

- Foundation of base-level activation in the environment
    - Authors:
        - Dr. John Anderson
- Behavioral models of non-pharmaceutical interventions in epidemics
    - Authors
        - Christian Lebiere
- Modeling the role of human memory and expectations in social exchange
    - Authors
        - Dr. Jonathan Morgan

28th ACT-R workshop ~ Human-machine teaming

- Combining ACT-R models with EEG data
    - Author: Linda Heimisch
- Cognitive mechanism for calibrating trust and reliance on automation
    - Author: Dr. Leslie Blaha
- AN ACT-R model of collaborative skill acquisition in Coop space Fortress
    - Author: Cvetomir Dimov
- Explorations of ACT-R, cognitive code, and teachable agents
    - Author: Dario Salvucci

28th ACT-R workshop ~ Cognition in complex task environments

- Impacts on cognitive decay and memory recall during long duration spaceflight
    - Author:
        - Terry Rector
- Learning and forgetting curves for a complex task with 3- to 14-day retention intervals: implications for ACT-R
    - Author:
        - Frank E Ritter
- Modeling well-learned idiosyncratic non-optimal microstrategies
    - Author:
        - Emily Greve
        - Robert West

28th ACT-R workshop ~ Future of ACT-R

- ACT-R updates
    - Author:
        - Daniel Bothell

**Recinormal room**

Learning

- How personalization guides (or distorts) learning: A model-based explanation
    - Authors:
        - Giwon Bahg
        - Mr. Matthew Galdo
        - Ryan Day
        - Vladimir Sloutsky
        - Dr. Brandon Turner
    - Abstract: In reality, our understanding of the world is often affected by the interaction with other (natural or artificial) cognitive agents. Personalization algorithms have been discussed as an influential component on the internet that possibly limits the pursuit of accurate knowledge, causing confirmation bias and polarization (e.g., Pariser, 2011). However, there has been no mechanistic explanation of how such personalization affects internal cognitive processes and learned knowledge. In this study, we aim to explain using a model-based approach how the interaction with personalization algorithms can hinder optimal category learning. Here, we assume that an exemplar-based learner experiences a baseline, self-directed, or curated learning sequence, while adapting one's attention via gradient-based optimization (e.g., Krushcke, 1992; Galdo, Vladimir, & Turner, submitted). In the two experimental conditions (i.e., self-directed, curated), either the learner or the external curation algorithm had control over items and features to be learned. Simulation experiments revealed that a personalized learning process can distort the latent representations of categories and misguide learners' attention, even when a learner is well-intentioned. This observation was generalizable to different datasets with various underlying structural forms. Lastly, when the learners' knowledge was tested using an independent test dataset, personalized learners tend to show overconfidence about their decisions compared to their predictive accuracy.
- Testing a learning and retention theory with a complex task with 3- to 14-day retention intervals
    - Authors:
        - Sarah Ricupero
        - Mr. Jacob Oury
        - Dr. Martin K.-C. Yeh
        - Farnaz Tehranchi
        - Ashley McDermott
        - Dr. Peter Weyhrauch
        - Mr. William Norsworthy
        - Frank E Ritter
    - Abstract: Introduction: We conducted a study (N=100) during the COVID-19 pandemic of learning a complex task (i.e., using multiple types of knowledge), troubleshooting single-fault scenarios on a 51-component hierarchical system based on a real radar over multiple days to measure how learning and retention are

affected by the training and retention schedule. The schedule is based on a published ACT-R model presented at ICCM. Method: Participants completed 1, 2, or 4 practice sessions on consecutive days that included a 27-minute session studying the material using an online tutor, a 5-minute practice session troubleshooting the simulation and a declarative and recognition memory assessment about the radar. After the practice session(s), participants returned after a delay for a test session that included a memory assessment, a troubleshooting session, and a working memory test. Delays ranged from 3 to 14 days (9 conditions, N=10/condition). The last of the 403 sessions was 30 April 2021. Results: We expect to see a learning curve and a retention curve on a complex task over relatively long learning and retention periods. We expect to see three different retention curves representing declarative decay, mixed decay, and procedural knowledge decay. The effect of delay between practice and test is expected to be moderated by the number of practice sessions. Conclusion: We will present preliminary data on a complex task learned up to four times with delays up 14 days. Results will be compared with the ACT-R learning and retention equations, including suggestions for changes to the theory.

- Network analysis of emerging vocabularies reveals different developmental trajectories in children with autism spectrum disorders
    - Authors:
        - Stan West
        - Dr. Eileen Haebig
        - Dr. Chris Cox
    - Abstract: Network analyses of typical language development indicate that words associated with many other words are acquired earlier, implying that typically developing (TD) children are sensitive to the semantic structure of their environment. Children with autism spectrum disorders (ASD) often lag behind their TD peers with respect to language acquisition, despite relatively spared statistical learning and fast-mapping skills. Recent work indicates that children with ASD may struggle with processing the semantic relationships that are the basis for word meaning. We acquired parent-report vocabulary checklists (Communicative Development Inventory; CDI) for 203 ASD children aged 11 – 173 months from the National Database of Autism Research and for 1,096 vocabulary matched TD children aged 11 – 30 months from WordBank to establish vocabulary composition. To estimate the semantic structure of these vocabularies, we referenced child-oriented word association data to construct an associative network from each child's vocabulary. Network structure statistics were modeled as a function of group (TD/ASD) and vocabulary size (linear, quadradic, and cubic trends). Network structure developed along different trajectories for each group as vocabularies grew. This began early in vocabulary acquisition, with vocabularies in the ASD group developing clusters more rapidly than the TD group until acquiring about 150 words. After that point, network statistics converged between groups as vocabularies become more similar (i.e., they begin to saturate the CDI wordlist). This suggests that children with ASD have a distinctive trajectory of vocabulary growth that, relative to TD children, is more oriented towards clusters of semantically related words early in language acquisition.
- Functional generalization and asymmetric learning in a feature-based bandit task

- Authors:
  - Dr. Maarten Speekenbrink
- Abstract: Multi-armed bandits are a useful paradigm to study how people balance exploration (learning about the value of options) and exploitation (choosing options with known high value). When options are distinguished by features predictive of reward, exploration aids generalization of experience to unknown options. The present study builds on our earlier work on human exploration and generalization in a feature-based bandit task (Stojic et al., 2020). Here, I present results from a new experiment where novel options are introduced regularly in three different environments: options either only provide rewards (gain), only provide punishments (loss), or can both provide rewards or punishments (mixed). Options were represented by randomly generated tree-like shapes, with features determining the angle and width of branches. Value of the options was a nonlinear function of the features. Regardless of the environment, people were quite good at choosing the best option. When first encountering each novel option, whether that option was chosen depended on the relative value of the option, indicative of successful function generalization. Compared to the other environments, exploration of novel options was generally larger in the loss environment. Computational modelling provides further insights into these results. We contrast a model that employs function learning through Gaussian Process regression with a new model that learns the value of options through a hierarchical Bayesian filter. Both models can employ a Bayesian mechanism to allow for asymmetric learning rates for positive vs negative reward prediction errors. Some evidence for such asymmetric learning is found.

- Common mechanisms for between- and within-trial learning dynamics
  - Authors:
    - Dr. Emily Weichart
    - Mr. Matthew Galdo
    - Vladimir Sloutsky
    - Dr. Brandon Turner
  - Abstract: Two of the most fundamental difficulties we face when learning is deciding which information is relevant, and when to use it. To overcome these difficulties, humans continuously make choices about which dimensions of information to selectively attend to, and monitor how useful those dimensions are in the context of the current goal. Although previous theories have specified how observers learn to attend to relevant dimensions over time, those theories have largely remained silent about how attention should be allocated on a within-trial basis, which dimensions of information should be sampled, and how the temporal ordering of information sampling influences learning. Here, we use the Adaptive Attention and Representation Model (AARM) to demonstrate that a common set of mechanisms can be used to specify: 1) how the distribution of attention is updated between trials over the course of learning; and 2) how attention dynamically shifts among dimensions within-trial. We validate or proposed set of mechanisms by comparing AARM's predictions to observed behavior in the context of five case studies, which collectively encompass different theoretical aspects of selective attention. Importantly, we use both eye-tracking and choice response data to provide a

stringent test of how attention and decision processes dynamically interact. Specifically, how does attention to selected stimulus dimensions gives rise to decision dynamics, and in turn, how do decision dynamics influence our continuous choices about which dimensions to attend to via gaze fixations?

- Contrasting mechanisms of depression by means of cognitive tasks and computational models
    - Authors:
        - Mr. Anmol Gupta
        - Marieke Van Vugt
    - Abstract: There are considerable differences of opinion about the underlying mechanisms of major depressive disorder. While some emphasize the importance of reward learning, others focus more on a negative mood, and still others emphasize the role of getting stuck in persistent negative thinking. In this task, I will present data from various tasks assessing these different cognitive mechanisms, and show that while impairments in reward learning are associated with depression scores, objective measures of persistent negative thinking are associated with rumination scores. I will then discuss how ACT-R models can explain the effects of persistent negative thinking on task performance in various tasks.

Model construction

- How many instances come to mind when making probability estimates?
    - Authors:
        - Dr. Joakim Sundh
        - Dr. Jianqiao Zhu
        - Nick Chater
        - Prof. Adam Sanborn
    - Abstract: Human probability judgments are variable and subject to systematic biases. Sampling-based accounts of probability judgment explain such idiosyncrasies by assuming that people remember or simulate instances of events and base their judgments on sampled frequencies. In the sampling-based framework, biases have generally been explained either by an additional noise process corrupting sampling (Probability Theory + Noise account), or as a Bayesian adjustment to the uncertainty implicit in small samples (the Bayesian sampler). These accounts both explain data well but because they can generally be expressed by the same equation their predictions are very difficult to distinguish from each other, despite describing qualitatively different processes. To this end, we have developed a method that uses a linear model of the relationship between the mean and the variance of repeated judgments. This model serves two purposes: Firstly, it can be used to provide a crucial test between these two accounts, validating the Bayesian sampler account. Secondly, because the variance of a binomial variable is directly dependent on the number of samples, it can be used to estimate (among other parameters) the number of samples used for each judgment, which for probability judgments are found to be rather small (< 10). This is particularly important because, although sampling-based models have become increasing popular, little attention have hitherto been given to estimating the precise number of samples people use. We hope that, in the long run,

the principle behind this simple model can be used to estimate sample sizes in a broader context.

- Differentiating dreams from wakefulness by automatic content analysis and support vector
    - Authors:
        - Ms. Xiaofang Zheng
        - Richard Schweickert
    - Abstract: Dream content is connected to major concerns of the individual's waking life (e.g., Domhoff & Schneider, 2008a, 2008b). Despite long investigation with laborious content analysis coding, dreams are far from well understood. Automatic quantitative analysis techniques can be not only faster than traditional human hand-coding but also lower in coding errors and bias, and deserve further investigation. Linguistic Inquiry and Word Count (LIWC, Pennebaker, Boyd, Jordan, & Blackburn, 2015) is an automatic technique possibly useful for dream research. We analyzed dream reports and waking life reports of individuals using LIWC and found differences in social content and other aspects. Furthermore, we used a machine learning technique, support vector machines, to detect whether a report described waking life or dreams, based on the LIWC word frequencies of various categories. Automatic content analysis techniques are promising for scientific research on dreams.
- Blind Man's Bluff: Formalizing theory-of-mind reasoning in a classic model of common knowledge
    - Authors:
        - Noah Burrell
        - Prof. Jun Zhang
    - Abstract: There are many variations of a classic example from game theory for differentiating knowledge and common knowledge. We revisit that example in the form of the "Blind Man's Bluff" game, which involves three players reasoning about the color (red or black) of a playing card they drew. Each player holds their card on their forehead to reveal it to the others but conceal it from themself. They reason about their own card based on the actions chosen by the others after a helpful announcement from a trustworthy friend. The primary mandate of the game is that a player will announce that their card is red upon deducing that fact with certainty, and thereby win the game. Suppose each card is red (the true state of the world). No player knows the color of their own card, and so none can yet win, but each player does possess the knowledge that not every card is black. However, only after their friend announces "not every card is black"—making that private knowledge common knowledge— does it become certain that at least one player will deduce their own card is red and, consequently, announce that fact to win the game. In this game, we formalize the Theory-of-Mind (ToM) reasoning in- volved in refining each player's possibility partition, which describes the sets of states of the world that are indistinguishable to them given the available information, following the friend's initial announcement and the subsequent action choices. We focus on how the refinement process does not require knowledge of any specific announcement or action—only common knowledge of the sequential information revelation process. Our framework

applies the concept of a "rough approximation" (from Rough Set theory). We find that the upper approximation of a player's possibility partition defined by another player's possibility partition has a clear ToM interpretation, though the meaning of the lower approximation is less obvious. We also consider the role of strategies, which map a player's information to a choice of action, and contrast the perception- based strategies used in the game with inference-based ones. To deal with common knowledge about strategies, we construct a modified, but informationally-equivalent game that involves repeated announcements from the friend instead of sequential action choices by the players. In this way—via a common knowledge device—our framework decouples, for the first time, the recursive ToM reasoning process from the information revelation process in a multi-stage game of incomplete information.

- Fast and flexible: Human program induction in abstract reasoning tasks
    - Authors:
        - Aysja Johnson
        - Todd Gureckis
        - Wai Keen Vong
        - Brenden Lake
    - Abstract: The Abstraction and Reasoning Corpus (ARC) is a challenging program induction dataset that was recently proposed by Chollet (2019). Here, we report the first set of results collected from a behavioral study of humans solving a subset of tasks from ARC (40 out of 1000). Although this subset of tasks contains considerable variation, our results showed that humans were able to infer the underlying program and generate the correct test output for a novel test input example, with an average of 80% of tasks solved per participant, and with 65% of tasks being solved by more than 80% of participants. Additionally, we find interesting patterns of behavioral consistency and variability within the action sequences during the generation process, the natural language descriptions to describe the transformations for each task, and the errors people made. Our findings suggest that people can quickly and reliably determine the relevant features and properties of a task to compose a correct solution. Future modeling work could incorporate these findings, potentially by connecting the natural language descriptions we collected here to the underlying semantics of ARC.
- Explaining away differences in face matching
    - Authors:
        - Necdet Gurkan
        - Jordan W. Suchow
    - Abstract: Unfamiliar face processing is often studied in the context of face matching, where an observer judges whether two images depict the same individual. On matching trials, the two images depict the same person but differ by factors. On non-matching trials, the two images depict different people, chosen in part because of their resemblance to each other. Accurate performance benefits from a representation of identity that is invariant both to state-based changes (e.g., in viewpoint, pose, and illumination) and to structural or surface-level changes to the faces themselves — e.g., those caused by aging or body modification. Here, we cast the problem of face matching as one of causal inference where the observer infers

whether the depicted person underwent a transformation or is a different person. We introduce a causal model of face matching in which the observer infers which factor best explains the observed differences between a pair of faces. Our model produces a classic phenomenon in causal inference — explaining away — whereby two independent causes become dependent conditioned on a common effect. We then provide support for the model in two experiments that asked participants to make face matching determinations and explain them. We find that observers have a rich understanding of the causal mechanisms that affect identity and appearance and can use that knowledge to make accurate inferences unattainable by approaches that rely only on feature detection and comparison.

- Instance-based cognitive modeling: a machine learning perspective
    - Authors:
        - Konstantinos Mitsopoulos
        - Sterling Somers
        - Christian Lebiere
    - Abstract: Cognitive Instance-Based Learning (CogIBL) model is a cognitive framework implemented within the constraints of ACT-R principles. This formulation though, defined within the Cognitive Science field, does not reveal the model's full strength and capabilities. In this work, we show that CogIBL, essentially, implements Kernel Smoothing, a non-parametric Supervised Learning function approximation method. Under this perspective, abstracted from cognitive concepts and expressed as a statistical learning algorithm, we argue that all CogIBL's implementations fall under two main learning paradigms: Supervised Learning and Reinforcement Learning. This new perspective has multiple benefits. First, it reveals CogIBL's structural differences from parametric approaches such as Neural Networks. It links it with well-studied statistical learning theory which provides theoretical guarantees of convergence, reveals its properties at full and establishes good evaluation practices highlighting where the model should expected to perform well and why. Second, the model, under the new formulation, can be implemented with popular tensor libraries such as Tensorflow and Pytorch making it scalable and fully parallelizable. This enables it to interact with prevalent Reinforcement Learning libraries such as OpenAI gym and Deepmind Lab, get trained in parallel with synchronous updates, and output multiple decisions at the same time. Finally, we discuss what this new approach reveals about the strength and weaknesses of the model and how a modeler can benefit from these.

Decision making

- Modelling appetitive-disinhibition in modified stop-signal task: A computational model of associative memory initiated going (disinhibition) system
    - Authors:
        - Ms. Akira Banerjee
    - Abstract:Studies employing modified Stop-signal tasks (MSST) have demonstrated that response-inhibition, a key executive-function, severely impairs in appetitive environments. These studies demonstrate that presence of appetitive-cues results in disinhibited response and slow-stopping latencies (i.e., Stop-Signal Reaction-Times or SSRT's). Theoretical-frameworks propose that retrieval of appetitive-cue

approach/going-response associations (developed during appetitive-conditioning) from one's associative-memory traces, biases the inhibitory system such that it produces approach/going (i.e., disinhibited-response) post-exposure to appetitive-cues. Aims: The aim of the current study was to develop a computational model of response-disinhibition i.e., a going-system. In developing this model, we introduced a new free-parameter 'λ' which instantiated associative-memory recall. We augmented λ to the Interactive Race Model (IRM) of action suppression to model the interaction between the associative-memory (i.e., λ) and inhibitory-system (i.e., IRM) with an aim to simulate disinhibited-responses (indicated by slow SSRT's) observed in MSST studies. Methods: We tested three model types that differed in how λ affected go-process and stop-process in IRM formalism. In the first model (Associative-Memory Interactive Disinhibition-Model–AMI) the λ parameters affected the mutual inhibitory-interaction between go-process and stop-process. In the second model (Associative-Memory Race Disinhibition-Model–AMR) λ parameters affected the mean growth-rate of go-process and stop-process. In the final model (AssociativeMemory Interactive Race Disinhibition-Model–AMIR) λ parameters affected both mean growth-rate and mutual inhibitory-interaction between go-process and stop-process simultaneously. Results: The modeling results indicated that out of the three models, only the first model–AMI, produced slow SSRT's observed in appetitive-cue conditions in MSST studies. Conclusion: The current study validated the theoretical propositions that associative memory and inhibitory-system interact with each other in producing appetitive-cue initiated disinhibition. It specifically highlighted that associative-memory affects the mutual inhibitory interaction (between go-process and stop-process) aspect of the inhibitory-system in giving rise to appetitive-cue initiated disinhibited-responses observed in MSST studies.

- Applying signal detection theory to evaluate bias in expert and novice predictions for NFL games
    - Authors:
        - Lauren Montgomery
        - Michael Lee
    - Abstract: The standard signal detection theory (SDT) model often uses an unbiased optimal criterion based on the assumption that the signal and noise distributions have roughly equivalent frequencies of occurrence. However, in some situations, optimal decisions should exhibit some partiality toward one distribution over the other. A real-world example is choosing between the home and away team in a sporting contest, since home teams do have a greater probability of winning. We considered the context of experts and novices predicting the winning team for the 256 games in the 2017 National Football League (NFL) season. We applied hierarchical SDT models to expert predictions provided by nflpickwatch.com and novice predictions collected during the 2017 NFL season to evaluate different biases in their predictions. We were particularly interested in the following biases: (1) home team advantage, (2) the cumulative win-loss record of teams, (3) herding by making the same prediction as other experts, (4) selecting the team with an unexpected win from the previous week, and (5) selecting against the team with an unexpected loss from the previous week. We then investigated patterns in how experts and novices used the 5 biases with a latent trait extension to our hierarchical SDT model. Applying the SDT models

provides a way to measure the under- or over-reliance that experts and novices have on these biases when making predictions, and the latent trait extension helps us evaluate differences between expert and novice use of the biases.

- Gaze dynamics in many-option choice
    - Authors:
        - Wenjia Joyce Zhao
        - Dr. Armin Thomas
        - Dr. Sudeep Bhatia
        - Prof. Ian Krajbich
    - Abstract: Attention is a key determinant of value-based choice. Yet we currently lack a general quantitative framework capable of providing a systematic account of attentional dynamics in large and complex choice sets, such as those encountered by decision makers in everyday choice settings (e.g. when choosing products in a grocery store). We build such a framework and apply it to eye-tracking data from a many-option food choice experiment. Our approach is based on established theories of attention and memory, and describes nuanced aspects of visual search dynamics, i.e., where people look at a given point in time and how this depends on what people have looked at previously. Our model quantitatively predicts key properties of the gaze patterns in the data such as the high probability of sampling neighbors, the frequent sampling and resampling of high-value items, and the delays before returning to an item. Overall, our quantitative, tractable, and general modeling framework provides novel insights regarding visual search dynamics in complex value-based choice. In doing so, it allows for the study of difficult but intriguing research questions regarding the interaction between attention and choice in everyday decisions.
- A sequential sampling account of semantic relatedness decisions
    - Authors:
        - Mr. Peter Maximilian Kraemer
        - Sebastian Gluth
        - Dr. Dirk Wulff
    - Abstract: Semantic relatedness, the degree to which a pair of concepts is related, is a key variable in modeling semantic memory. Researchers have been assessing this variable with semantic relatedness decision tasks (SRDT). In SRDT, participants judge within a 2-alternative-forced choice setting whether they consider two concepts to be semantically related or not. Choices and response times in the SRDT are usually interpreted in the light of spreading activation in semantic networks. However, spreading activation alone is insufficient to explain critical behavioral benchmarks. These include the inverted U shape of response times as a function of semantic relatedness (Kenett et al., 2017) and the relatedness effect according to which “related” choices are generally faster than “unrelated” choices (Balota & Black, 1997). Here we propose that sequential sampling models of decision making, which draw on spreading activation dynamics, and on decision aspects from signal detection theory, can account for the two benchmarks. In a simulation study, we obtained behavioral predictions for three sequential sampling models, the Race model, the Leaky Competing Accumulator model (LCA) and the Drift Diffusion Model

(DDM). We found that the LCA and DDM can predict both benchmarks. Interestingly, the LCA predicted that the relatedness effect reverses for weakly related concepts, implicating faster “unrelated” choices than “related” choices. This inverted relatedness effect describes a novel prediction, not yet reported in the literature. Testing this prediction on a data set by Kumar et al. (2019), we found empirical support for the inverted relatedness effect. Overall, our work highlights the importance of considering decision-related processes when studying semantic memory. Sequential sampling models constitute a productive modeling framework for semantic decision tasks.

- The Race Levy Flight Model: Jumping in multi-alternative decisions
  - Authors:
    - Mr. Amir Hosein Hadian Rasanan
    - Dr. Jamal Amani Rad
    - Dr. Nathan J Evans
    - Dr. Amin Padash
  - Abstract: Sequential sampling models have become the dominant explanation for how information processing operates in decision making. One recent variant of these models, the Levy Flight model (Voss et al. 2019), proposes non-Gaussian noise for the evidence accumulation process, which theoretically implies that evidence accumulation may involve noisier “jumps” than those contained in models with Gaussian noise. While the Levy Flight model proposed by Voss et al. (2019) was shown to provide a better account of their data than the standard diffusion model, this formulation has two key weaknesses: (1) it does not have an exact likelihood function, and (2) it is only applicable to 2-alternative tasks. Here, we develop the Race Levy Flight Model (RLFM): a Levy Flight model that utilizes a racing accumulator framework with non-Gaussian noise. Importantly, the independent accumulator framework allows for an easy extension to multi-alternative decisions and the calculation of the first passage time for each accumulator using a fractional partial differential equation, providing a Levy Flight model that has an exact likelihood function for any number of decision alternatives. To assess the performance of our proposed RLFM, we fit the model to the speed-accuracy emphasis data-set of Forstmann et al. (2008). Our results show that the RLFM greatly outperforms the racing diffusion model, showing an advantage for the Levy Flight process consistent with the findings of Voss et al. (2019), and produces a theoretically sensible ordering of parameter estimates across speed-accuracy conditions.
- Not great, not terrible: A reward “landscape” analysis of time-varying decision thresholds
  - Authors:
    - Mr. Erik Stuchlý
    - Casimir Ludwig
    - Gaurav Malhotra
  - Abstract: Normative models of perceptual decision-making predict that time-varying decision policies, such as collapsing decision thresholds, represent the optimal strategy in certain contexts. Nevertheless, experimental studies often reveal systematic differences between the model-inferred optimal threshold and the thresholds adopted by participants. Malhotra et al. (2018, J. Exp. Psychol. Gen.)

computed the reward rate of decision thresholds with different intercepts and gradients – the 'reward landscape' - and found that the optimal policy in their task was adjacent to policies with extremely low reward rate. They proposed that the observed choice of sub-optimal thresholds is a result of satisficing, whereby participants explore this landscape and settle for policies distant enough from those which yield low reward rate, while still being near-optimal. If this hypothesis holds, then lowering the reward rate of all non-optimal policies, while keeping the optimal policy unchanged, should motivate participants to adopt thresholds closer to the optimal policy. We report findings from Monte Carlo simulations used to generate the reward landscape, which identified two task parameters that change the reward rate of thresholds around the optimal policy, while keeping the optimal policy unchanged: monetary penalty and inter-trial interval for incorrect decisions. We manipulated these parameters in an experimental task to identify participants' position on the reward landscape and to examine how sensitive they are to changes in this landscape. By considering a broad range of decision policies in this fashion, we can reach a better understanding of why and how time-varying decision strategies are used

Memory models

- Cognitive modeling of free association
    - Authors:
        - Russell Richie
        - Ada Aka
        - Dr. Sudeep Bhatia
    - Abstract: Free association among words is a fundamental and ubiquitous memory task, yet there have been few attempts to apply established cognitive process models of memory search to free association data. We address this by using a simplified variant of a popular recurrent neural network model of recall, the Context Maintenance and Retrieval (CMR) model, which we fit on a large free association dataset. We find that this network, with response biases and asymmetric cue-context and context-cue weight matrices, outperforms previous models without these components (which emerge as special cases of our model), on a variety of metrics including prediction of association asymmetries. We also find that continued free association, where the participant provides multiple responses to a single cue, is best described with a combination of (a) a partially decaying context layer, where representations of the cue and earlier responses are largely maintained over time and (b) a weak but persistent and non-decaying effect of the cue. This network also accounts for 'response chaining' effects in continued free association, whereby earlier responses seem to prime later responses. Finally, we show that training our CMR variant on free association data generates improved predictions for list-based recall, demonstrating the value of free association for the study of many different types of memory phenomena. Overall, our analysis provides new explanations for empirical findings on free association, predicts free association with increased accuracy, and integrates theories of free association with established cognitive process models of memory.
- Modeling memorability with semantic representations

- Authors:
  - Ada Aka
  - Dr. Sudeep Bhatia
  - Dr. John McCoy
- Abstract: What kinds of words are more memorable? Can we use insights from data science and high-dimensional semantic representations, derived from large-scale natural language data, to predict memorability? In Study 1, we trained a model to map semantic representations directly to recognizability and recallability of 576 unique words from a multi-session mega-study. Specifically, we tested how well we could predict the average memorabilities of words using their vector representations. Leave-one-out cross validation results demonstrated that our model was able to reliably predict which words are more likely to be recognized and recalled with very high accuracy (r = 0.70, 95% Confidence Interval (CI) = [0.656, 0.739]). We next compared our model predictions to an alternative psycholinguistic model which was only trained on conventional word properties such as concreteness and word frequency (r = 0.28, 95% CI=[0.203, 0.353]). Despite previous work in the memory literature that have consistently demonstrated the importance of psycholinguistic properties, our method of mapping rich semantic representations to recognition and recall data outperformed this alternative model. Combining semantic representations and psycholinguistic properties, however, further increased our models' predictive power (r = 0.72, 95% CI=[0.679, 0.757]). In Study 2, we sought to examine and interpret the information contained in semantic representations that gives rise to these successful predictions. We studied individual words and concepts that are most (vs. least) strongly associated with different words in our study word pool in these multi-dimensional spaces. These associations allowed us to characterize the variability in memorability across different study words and determine which attributes, traits, and concepts are most associated with the words that participants were more likely to remember. Results of this study highlighted top constructs that were related to memory performance. These constructs included those relating to humans (e.g., family-, female-, male-related constructs), emotions, and arousing situations. Altogether, we introduced a computational approach that can generalize its learned mappings to make quantitative predictions for the memorability of millions of words or phrases with semantic representations, without the need of any further participant data. In addition, we were also able to identify psychological concepts and constructs that are most-related to high (or low) memory performance. Thus, we provide evidence that using high-dimensional semantic representations is a powerful predictive tool to shed light on which words are more likely to be remembered and what the underlying psychological constructs of successful memory may be.

- Fitting a revised version of the feature model via Approximate Bayesian Computation
  - Authors:
    - Dr. James Yearsley
  - Abstract: Memory models supply many examples of a common feature of computational cognitive modelling; namely that a model may be simple to describe and simulate and yet have no closed form expression which permits it to be fit via maximum likelihood estimation, or similar techniques. One such model is the Feature

Model (Nairne, 1988, 1990; Neath & Nairne, 1995) which was developed to model immediate serial recall. In recent work we have used Approximate Bayesian Computation methods to fit both the original and a revised version of the feature model to data from serial recall, free recall, and order reconstruction tasks. We will discuss the Revised Feature Model (RFM) and the procedure for fitting it to data by considering the example of the production effect; a well-known encoding effect, according to which when some words within a list are read aloud during study they are better remembered than words read silently. The RFM accounts for the production effect via a combination of relative distinctiveness and the costs of the richer encoding associated with production, and we will show that it provides a good account of the production effect in both immediate and delayed recall tasks. The success of this approach means the Revised Feature Model can now be added to the set of memory models that may be quantitatively fit to data, and compared with each other.

- Imaginary ELFs and other things you've never seen before: A comparative analysis of computational memory models on the fan and extra-list feature effects
    - Authors:
        - Dr. Alex Kelly
    - Abstract: How do humans judge that a stimulus is novel? Novelty judgement is a fundamental property of human memory and an important problem for artificial intelligence. While computational memory models can predict speed and accuracy of recall and recognition, many models fail to predict response time and accuracy on rejected foil items in experimental tasks. We present a formal analysis of computational models of human memory, including MINERVA (Hintzman, 1986), IRM (Mewhort & Johns, 2005), ACT-R DM (Anderson, 2009), and HDM (Kelly, Arora, West, & Reitter, 2020). We test the models on two tasks: the fan effect (Anderson, 1974) and the extra-list feature (ELF; Johns & Mewhort, 2003) effect. The models are able to perform the fan effect on target items when using a multiple recall strategy, but not when using a recognition judgement or single recall. To account for the ELF effect, we propose a new model that uses complex-valued vectors. We compare and contrast our model to existing models and discuss the implications of our theoretical findings for memory modelling and deep learning.
- Free associations as steady states in dynamic spaces
    - Authors:
        - Kevin Shabahang
        - Dr. Hyungwook Yim
        - Prof. Simon Dennis
    - Abstract: The free association task provides a glimpse into the organizational structure of concepts in memory and has been used by theorists as a benchmark for computational models of semantic processing. While descriptive accounts like the Topics model and Latent Semantic Analysis have been shown to match free association data, to date no process model has been tested. We compared three descriptive models (Topics, LSA and word2vec, Mikolov et al., 2013) and two process models (Dynamic Eigen Network and BEAGLE; Jones & Mewhort, 2007). Overall, word2vec showed the best match to the South Florida free association

norms. Of the process models, the DEN outperformed BEAGLE. When association pairs were characterized as either forward, backward, syntagmatic, paradigmatic, form-based or other, the profiles of performance of the models were remarkably similar. All models failed to capture form-based associations, as would be expected, and also performed best on paradigmatic associations.

Neurocognitive modeling

- Can we directly observe stages of cognitive processing? EEG-based identification of evidence accumulation stages
    - Authors:
        - Hermine Berberyan
        - Leendert Van Maanen
        - Hedderik van Rijn
        - Dr. Jelmer Borst
    - Abstract: Traditionally, processing stages were investigated using behavioral measurements. To better capture the ongoing process, researchers have recently turned to neuroimaging methods instead. In that frame, a novel machine learning algorithm, hidden semi-Markov model multivariate pattern analysis was introduced (HsMM-MVPA; Anderson, Zhang, Borst, & Walsh, 2016). The goal of the current project was to validate HsMM-MVPA as a method for discovering stages directly from EEG data. To that end, two simple visual discrimination tasks were designed in which perceptual processing and decision difficulty were manipulated. For comparison with standard RT-based methods, the HsMM-MVPA analysis was complemented with evidence accumulation models (EAMs). The results of the analysis revealed that five-state HsMMs accounted for the data in all tasks. The brain activation of one of those stages was dependent on perceptual processing, while the brain activation and the duration of two other stages were dependent on decision difficulty. Consistent with the HsMM-MVPA results, EAMs showed that non-decision time varied with perceptual difficulty and drift rate value with decision difficulty, respectively. Additionally, non-decision and decision time of the EAMs correlated highly with the first two and the last three stages of the HsMM-MVPA analysis, respectively, indicating that the HsMM-MVPA analysis gives a more detailed description of stages discovered with this more classical method. Our conclusion is, therefore, that cognitive stages can be directly inferred from EEG data with the HsMM-MVPA analysis.
- A model-based cognitive neuroscience account of cognitive control
    - Authors:
        - Anna-Lena Schubert
        - Christoph Löffler
        - Prof. Dirk Hagemann
    - Abstract: Cognitive control processes play an important role in many substantial psychological theories, but are hard to reliably and validly measure on the subject-level (Hedge et al., 2018; Rouder et al., 2019). Therefore, associations between individual differences in cognitive control and other variables are often inconsistent. Here we present a model-based cognitive neuroscience approach of cognitive

control in which we integrated a mathematical model– the dual-stage two-phase model (Hübner et al., 2010) – with electrophysiological correlates of selective attention. We analyzed data from 149 participants who completed the Eriksen Flanker task while their EEG was recorded. We used structural equation modeling to a) improve the reliability and precision subject-level estimates by modeling them on a latent level and b) directly test competing theoretical higher-order linking structures between model estimates and latencies of the lateralized readiness potential. We will demonstrate that model parameters and neural correlates showed convergent validity and could be meaningfully related to each other. Together, these neurocognitive process parameters jointly predicted 37 % of the variance in individual differences in higher-order cognitive abilities. We propose that model-based cognitive neuroscience approaches can be used to overcome the measurement crisis of individual differences in cognitive control.

- Contralateral oscillations related to modulation of top-down attention in perceptual decision making: a Bayesian hierarchical diffusion model and EEG analysis
    - Authors:
        - Mr. Amin Ghaderi-Kangavari
        - Dr. Jamal Amani Rad
        - Dr. Kourosh Parand
        - Dr. Reza Ebrahimpour
    - Abstract: The neural mechanisms underlying attention-based perceptual decisions are of vital importance to a comprehensive understanding of behavior and cognition. Recent work has suggested that attention may play a key role in perceptual decision making. However, the exact cognitive components involved as well as the biomarkers of attention to predict behavioral performance in perceptual decisions have not yet been determined. To accomplish this, based on the Bayesian hierarchical diffusion model we have explored the underlying latent process of spatial attention in perceptual decision processes simultaneously at the group and individual level. The model's parameters discovery showed that non-decision time (encoding plus motor execution) received the smallest deviance information criterion (DIC) and largest R-square relating to prioritized and non-prioritized top-down spatial attention. Moreover, based on the event-related potential (ERP) analysis and multiple linear regression model, N2 sub-component contralateral amplitude at central electrodes and alpha power band at parietal-occipital can predict very well response time (RT) relating to to-down spatial prioritization. But, the non-decision time parameter was predicted by only the contralateral N2 sub-component and not contralateral alpha power. Conversely, ipsilateral N2 sub-component and alpha power could not interpret the modulation of spatial prioritization in the decision process. In order to verify the convergence of the Markov chain Monte Carlo (MCMC) sampling, the R-hat Gelman-Rubin statistic was under 1.0001 which appears that the best scenario of the diffusion model was superior convergence and the same stationary distribution.
- Getting blood from a stone: improving neural inferences without additional neural data
    - Authors:
        - David Halpern
        - Todd Gureckis

    - Abstract: In recent years, the cognitive neuroscience literature has come under criticism for containing many low-powered studies, limiting the ability to make reliable statistical inferences. Typically, the suggestion for increasing power is to collect more data with neural signals. However, many studies in cognitive neuroscience use parameters estimated from behavioral data in order to make inferences about neural signals (such as fMRI BOLD signal). In this paper, we explore how cognitive neuroscientists can learn more about their neuroimaging signal by collecting data on behavior alone. We demonstrate through simulation that knowing more about the marginal distribution of behavioral parameters can improve inferences about the mapping between cognitive processes and neural data. In realistic settings of the correlation between cognitive and neural parameters, additional behavioral data can lead to the same improvement in the precision of inferences more cheaply and easily than collecting additional data from subjects in a neuroimaging study. This means that when conducting an neuroimaging study, researchers now have two knobs to turn in a design analysis: the number of subjects collected in the scanner and the number of behavioral subjects collected outside the scanner (in the lab or online).
- Recovering parameters of joint models of human EEG and behavior during decision making
    - Authors:
        - Michael D. Nunez
        - Prof. Ramesh Srinivasan
        - Joachim Vandekerckhove
    - Abstract: Fitting drift-diffusion models (DDMs) to multiple participants' choices and response times during perceptual decision making tasks result in parameter estimates that have cognitive interpretations such as individual differences in speed-accuracy tradeoffs and the average rates of evidence accumulation. The cognitive interpretations of DDM parameters can then be verified with experimental conditions and manipulations. Fitting neural drift-diffusion models (NDDMs) to participants' scalp-recorded EEG as well as choices and response times can further reveal additional individual differences in cognition, such as individual differences in visual attention, visual encoding time (VET), and evidence accumulation processes. We discuss our recent efforts to develop NDDMs that are useful in understanding differences across individuals. In particular we are interested in models that actually recover parameters from simulated behavior and EEG data. Often newly developed NDDMs converge to a solution when using hierarchical Bayesian methods. However, whether the posterior distributions of parameters are informative about individual differences is not clear unless parameter recovery and parameter generalization to similar models are confirmed. In particular we discuss modeling efforts to understand individual differences in cognition that cannot be learned with models of either EEG or behavior alone.
- Inactivation of superior colliculus neurons affects interactive competition during rhesus monkey decision making
    - Authors:
        - Michele A. Basso
        - Elizabeth J. Jun

        - Ryan Kirkpatrick
        - Mr. Alex Bautista
        - Dr. Per Sederberg
    - Abstract: Understanding the decision-making process is crucial to any theory of cognition. A popular framework for the mathematical modeling of decision-making is the sequential sampling framework. Support for this framework comes from converging evidence from animal studies showing the implementation of processes similar to evidence accumulation in several brain regions. While there is continued debate about which brain regions play critical roles in the perceptual decision-making process, several recent studies suggest the superior colliculus (SC) is involved. In one such study, rhesus monkeys completed a simple perceptual decision-making task with and without inactivation of neurons in the intermediate layers of the SC via muscimol injection. The monkeys made fewer responses to targets presented in the inactivated receptive field and the correct responses made towards the inactivated field were slower than in the pre-inactivation condition. Previous work found that a Diffusion Decision Model (DDM) allowing the drift rate parameters to vary across the injection conditions was the preferred model for these data, implying that the inactivation of the SC affected the rate of evidence accumulation. Since muscimol is a GABA agonist and there are GABAergic neurons in the SC, it is possible that the muscimol inactivation affected the competitive dynamics instead of simply the drift rate. Subsequently, we build upon the prior work by fitting (in addition to the DDM) two models that instantiate competition, or the lack thereof, differently than the DDM: the race model and Leaky Competing Accumulator (LCA) model. When fitting to the data, we allowed either the drift rate, decision threshold, neural leak, or lateral inhibition to vary across the pre-inactivation and post-inactivation conditions. Regardless of which parameter was manipulated across conditions, the LCA models provided a better fit to more sessions than the DDM or race models. The two winning models were the LCA model where the drift rates decreased in the post-inactivation condition relative to the pre-inactivation condition, and the LCA model where the neural leak increased in the post-inactivation condition relative to the pre-inactivation condition. Our modeling results provide further evidence that the SC is involved in decision-making, and that interactive competition plays a key role in the dynamics of the accumulation process.

**T room**

Welcome mixer

- Start time: 12:00 EDT July 01, 2021
- End time: 13:00 EDT Jul 01, 2021

Monday mixer

- Start time: 18:00 EDT Jul 05, 2021
- End time: 19:00 EDT Jul 05, 2021

Fast talk session

- First-passage statistics for a model of word-by-word sentence parsing
    - Authors:

        - Dr. Garrett Smith
    - Abstract: A fundamental question in cognitive science is how people comprehend sentences word by word. An important step in sentence comprehension is determining the syntactic relationships between words (figuring out who did what to whom). Building these syntactic relationships is known to take differing amounts of time depending on the type of sentence and the words it contains. A good theory of sentence comprehension should not only say how syntactic relations are established but also how long it takes to establish them. Here, we analyze a new model that aims to accomplish both goals. At each word in a sentence, the model stochastically explores a network of discrete states. Each state consists of a partial parse of the sentence so far, i.e., some set of dependency links between head words and dependent words. The model can jump between states if they differ by a single link until it reaches a state corresponding to a complete parse of the sentence so far. We use the master equation to analyze this continuous-time random walk. We present formulas for first passage time distributions and splitting probabilities, which are treated as the predicted reading times for that word and the probabilities of building different alternative parses, respectively. We illustrate how we can gain new insights into known phenomena (temporary ambiguities like, "the horse raced past the barn fell") using these techniques. The hope is that these quantitative tools will facilitate comparisons with other sentence comprehension models and lead to new theory-driven experiments.
- Modelling order within associations in symmetric models of association memory.
    - Authors:
        - Jeremy Thomas
        - Jeremy B. Caplan
    - Abstract: Despite many examples of order-sensitive paired associates (e.g., FISH HOOK), the study of association memory (e.g., AB, CD) has been theoretically isolated from the study of order memory (e.g., ABCD). As a result, formal models of association memory are poor at accounting for within pair order (AB vs. BA), and either predict that order judgments of a retrieved pair should be at chance or perfect. Behaviour contradicts both predictions, when the pair can be recalled, order judgment is above chance, but well below perfect. We tested four separate order encoding mechanisms that could be added to existing convolution-based models, which otherwise predict chance order judgment performance, where pair order is encoded as: 1) positional item features, 2) position-specific permutations of item features, 3) position-item associations, and 4) adding position vectors to items. All models achieved close fits to aggregate order recognition data, without compromising associative symmetry. Although published models are unable to capture the relationship between memory for associations and their constituent order, multiple promising enhancements to convolution models are feasible.
- Measuring individual differences in the truth effect: A formal analysis
    - Authors:
        - Daniel Heck
        - Florence Bockting

- Abstract: The illusory truth effect refers to the phenomenon that participants tend to judge repeated statements as more true than new statements. The effect of repetition on truth judgments is measured as the difference of mean truth ratings between repeated and new statements (TE). An aspect which has received little attention concerns the use of natural-language statements as stimuli. Given that these statements evoke different individual mental representations, the question arises to what extent the TE does indeed measure an effect of repetition or rather a difference in prior plausibility between statements. We argue that the appropriateness of the TE depends on the research focus: group or individual level. While it is a valid measure of the effect of repetition on the group level, when using a counterbalanced design, it is potentially biased on the individual level. We use a mixed-model approach to formalize our theoretical argument and discuss the implications for the group as well as the individual level. We further support the relevance of these theoretical implications by simulating individual truth effects using extant data simulations. In this approach, empirical data are used as a data base to perform realistic simulations of variation in the population. Finally, we discuss consequences for research on individual differences in the illusory truth effect.

- A neurocomputational model of prospective and retrospective timing
  - Authors:
    - Joost de Jong
    - Dr. Aaron Voelker
    - Terry Stewart
    - Chris Eliasmith
    - Hedderik van Rijn
  - Abstract: Keeping track of time is essential for everyday behavior. Theoretical models have proposed a wide variety of neural processes that could tell time, but it is unclear which ones the brain actually uses. Low-level neural models are specific, but rarely explicate how cognitive processes, such as attention and memory, modulate prospective and retrospective timing. Here we develop a neurocomputational model of prospective and retrospective timing, using a spiking recurrent neural network. The model captures behavior of individual spiking neurons and population dynamics when producing and perceiving time intervals, thus bridging low- and high-level phenomena. When interrupting events are introduced, the model delays responding in a similar way to pigeons and rats. Crucially, the model also explains why attending incoming stimuli decreases prospective estimates and increases retrospective estimates of time. In sum, our model offers a neurocomputational account of prospective and retrospective timing, from low-level neural dynamics to high-level cognition.
- Bayesian nonparametric modeling: alternative item response theory models
  - Authors:
    - Dr. Vithor Franco
    - Dr. Gabriel Wallin
  - Abstract: Bayesian item response theory modeling is a complex issue as it requires the estimation of many parameters (at least one parameter per respondent and one per item). The problem is especially intricate when Bayesian nonparametric item

response theory models (BNIRMs) are used, as the number of parameters scale really quickly. Also, to guarantee the identifiability of the model, restrictions regarding the distribution of the true scores or the item response function (IRF) are used. The aim of the present study is to develop BNIRMs derived from optimal scoring, a new nonparametric psychometric approach that similar to Mokken Scale Analysis uses sum scores as initial guesses for estimating the IRFs. We propose four approaches for estimating the IRFs: the first two use basis expansion (Legendre and B-splines); the third one uses a single hidden layer neural network; and the last one is a new proposed way (developed in the present study) of doing of piecewise regression, which we call Rademacher basis. The priors for the regression coefficients of the bases follow a normal distribution with mean 0 and standard deviation equals to 1 for L2-regularization. For the priors of the latent true scores, we propose what we call a Kolmogorov-Smirnov prior, which uses the empirical cumulative distribution of the sum scores as an initial estimate for the distribution function. We provide Maximum a Posteriori estimation with Genetic Algorithm, as well as MCMC estimation with a Hit-and-Run algorithm. Comparisons between performances and future studies are discussed.

- A Bayesian account of two-factor theory of emotion process
    - Authors:
        - Mr. Lance Ying
        - Prof. Jun Zhang
    - Abstract: Bayesian inference has been used in the past to model visual perception (Kerson et al., 2004), accounting for the Helmholtz principle of perception of “unconscious inference.” In this paper, we adapt the Bayesian framework to model emotion in accordance with Schachter-Singer’s Two-Factor theory, which argued that emotion is the outcome of cognitive labeling or attribution of a diffuse pattern of autonomic arousal (Schachter & Singer, 1962). In analogous to visual perception, we conceptualize the emotion process, in which emotional labels are constructed, as an instance of unconscious Bayesian inference combining the contextual information with a person’s physiological arousal patterns. We develop a drift-diffusion model to simulate Schachter-Singer’s experimental findings. There, participants who were physiologically aroused (via drug injection but were not informed of arousal) later reported different emotions (i.e., labeled their arousal pattern differently) based on the nature of their interaction with a experimental confederate they encountered post-injection. In our drift-diffusion modeling, the decision boundaries correspond to the euphoric and anger state experienced by the participants in the experiment, and boundary-crossing constitutes “labeling” in Schachter-Singer’s sense. Response time (RT) in the drift-diffusion model is used as a surrogate measure of the self-rated intensity of the emotional state, where high intensity corresponds to a shorter response time. We propose two model scenarios (versions). In the first version, arousal pattern is used as the prior and the likelihood function for evidence accumulation is models the interaction with the confederate (context). We adopt an unbiased prior, while allowing the drift-rate (and its sign) to capture the nature of interaction with the confederate. In the second setup, we use the context as the prior and physiological arousal patterns as the likelihood function. We expect an initial bias depending on the polarity of the interactive experience with the confederate, but the

drift-rate is of zero-mean (diffuse but polarity-neutral arousal pattern). The comparison between the simulations of the two versions of the Bayesian drift-diffusion models and the original Schachter & Singer (1962) experimental data will be reported.

- Cognitive modeling in mathematical reasoning and problem solving
    - Authors:
        - Irma Elibeth Rugerio
        - Dr. Alfonso Díaz Furlong
    - Abstract: Research regarding the learning processes of mathematics is focused primarily on pedagogical, didactic, and teaching practice aspects. On the other hand, researchers have been working on the understanding of the cognitive processes related to the acquisition of mathematical concepts and methods. The convergence of different areas of knowledge can be especially useful to achieve this objective, tackling it from a multidisciplinary point of view. Cognitive modeling, mathematical psychology, and neurosciences are necessary approaches to study, research, and predict the phenomena related to mathematical learning and reasoning. From the study of categorization processes, memory, and multitasking aspects, it is possible to glimpse the dynamics involved in the development of mathematical thinking. In this research proposal we are interested in studying brain activity patterns through the use of an EEG device (CYTON Biosensing board 8-channels / Emotiv-EPOC + 14 channels), to later generate and implement a cognitive model that allows us to understand the process of developing mathematical skills and reasoning, specifically, for solving geometry problems by students of secondary education, high school, and early college years; this following the inspiration of past work of ACT-R concerning algebra problems frame. In this fast talk, we present the theoretical and methodological aspects of the research proposal and further applications.
- Characteristic learning process in insomnia
    - Authors:
        - Ms. Asako Toyama
        - Dr. Yoshihiko Kunisato
    - Abstract: Insomnia is a risk factor for various mental and physical diseases. Understanding the information processing that is unique to this disorder will help in its treatment. This study explores whether the severity of insomnia relates to any unique characteristic learning process distinguished from other symptoms. For this purpose, we used a decision-making task that can dissociate the influence of positive from negative outcomes on choice behavior by estimating dual learning rates. We recruited general participants using a crowdsourcing service. They performed the task online and completed self-report measures on insomnia, anxiety, and depression. The data gathered from 391 participants were analyzed. First, we found a strong correlation between the self-report measures, as predicted. Next, to explore unique learning processes associated with insomnia, we applied the reinforcement learning model to the data from the decision-making task and estimated the model parameters. The higher learning rate of positive outcomes over negative outcomes is a feature observed as a whole and can be used as an index of biased information processing in the learning process. Analyses using linear models revealed that this

index is higher in those with higher insomnia scores, which implies that insomnia is related to attention to positive outcomes. Interestingly, higher anxiety scores were predicted in the opposite direction. Possible explanations for the results may be differences in cognitive resources and attention biases. We also report other findings on the association between learning processes and mental health

- Context switching in machine minds
    - Authors:
        - Amit Singh
    - Abstract: Among many remarkable things the mind does, neuroplasticity stands in a league of its own. Central to this quality is the ability to render and infer different cognitive models for different tasks. Recent developments in machine learning have been fairly successful in optimizing for a single task (supervised learning with backpropagation). This however is not enough for general intelligence, where the agent is required to form abstractions (On the measure of intelligence, Chollet). Common ground to all the tasks is the fact that we can mathematically and geometrically model each one in the state space (S[ϕ]) with its state variable set ϕ. A neural network (NN[task]) is a universal function approximator and can be thought of mapping set of state variables along a manifold (M[task]), i.e. given {(X1,Y1),…,(Xn,Yn)}, NN builds f : X to Y learn via gradient descent. This approach introduces a new neural network (NN[meta]) which is trained to translate along all M[task] in the state space S[ϕ] learning a new meta-manifold (M[meta]) to traverse along tasks, revealing common parameters and eventually the latent model (l : task_m{x,y} -> task_n{x,y}), here x,y elicit different meaning depending on the task (context). Eventually, we are left only with the state variables that optimize for either tasks or translation over the tasks. This way the agent performs tasks through learning and switches context through model translation. Geometric interpretation of such model is an intuitive playground for all meta-learners.
- Sailing the seas of social uncertainty: Predicting COVID-19 health behavior through wisdom of the crowd
    - Authors:
        - Mr. James Adaryukov
        - Tim Pleskac
    - Abstract: COVID-19 immersed us in a sea of uncertainties, several social: Will people wear masks? Are they wearing them now? Will people vaccinate? We were curious how well the wisdom of the crowd could reduce these uncertainties. Across two studies, we surveyed 1,869 students at the University of Kansas on their likelihood of engaging in health-protective behavior, how likely they assumed others were to engage in that behavior, and their confidence in those estimates. We also asked them to predict how other students would respond and collected numeracy, discounting, and risk-taking propensity measures. We compared predictions from multiple wisdom of the crowd aggregation methods, including simple averaging, weighted averaging, and the surprisingly popular algorithm, which makes use of differences between self- and other-related beliefs. We found that weighting by confidence produced predictions that most closely approximated actual observed data for mask-wearing. However, surprisingly popular predictions also proved

accurate. We will discuss the implications of these findings, particularly in the context of identifying the environments when different wisdom of the crowd algorithms will work better or worse, and the challenges in using wisdom of the crowd algorithms to predict human behavior.

- Exploring estimation of social welfare functions for consensus
    - Authors:
        - Prof. Alex Davis
    - Abstract: Consensus is critical for problems ranging from policy decision-making to expert elicitation, yet research is lacking on methods for helping small groups come to consensus. We take advantage of a proof by Roberts (1980) that the level sets of cardinal fully comparable social welfare functions are cones with vertices at the equal utility point, where the angle of the cone can change depending on the region of the space of utility orders. We propose an approach that leverages an assumption about the relationship between the social welfare function across the n! regions. Specifically, we assume that the social welfare function's local behavior will be similar if the ordering of the utilities is similar across two regions of the order space. We compare the approach against alternative non-parametric and parametric approaches.
- Between-subjects speed-accuracy trade-off for a random dot motion task
    - Authors:
        - Mr. Tom Narraway
        - Dr. Scott Brown
        - Guy Hawkins
    - Abstract: How extreme can we make the speed-accuracy trade-off and still see adequate performance? At what point does does a participant just start guessing? 400 participants were assigned to one of eleven speed-accuracy emphasis groups. Each group experienced a different average deadline time throughout the entire experiment, ranging from 200 ms to 2500 ms. One group was used as an approximate control, where every trial had a six second deadline. Speed-accuracy was emphasised using implicit deadlines rather than explicit instructions. Response time and accuracy (of attempted trials) increased as deadline increased, and showed an interaction with trial coherence. The resulting figure looks pretty cool. Miss rate (of all trials) decreased as deadline increased, reaching nearly 0% for the control group.
- When synthetic portraits do not preserve privacy
    - Authors:
        - Jordan W. Suchow
        - Necdet Gurkan
        - Joshua Peterson
    - Abstract: Synthetic portraits are used as a privacy-preserving measure to train machine-learning models, anonymize faces through face replacement, and generate pseudonymous avatars. Here, we argue that while synthetic portraits may protect the privacy of some individuals, they do not protect the privacy of every individual with privacy interests in the images because of the statistical structure of human appearances. In particular, we demonstrate that the collection of actual appearances

is so densely arranged in face space that every synthetic portrait will necessarily capture the likeness of at least one actual current, past, or future person.

- Using Systems Factorial Technology to determine the fundamental cognitive properties of decision making
    - Authors:
        - Jakob Berg
        - Jenna Lester
        - Cara Kneeland
        - Prof. Joe Houpt
        - Mario Fific
    - Abstract: Most decisions people make depend on multiple sources of information and a number of models have been posited to explain how people combine those sources as part of their decision-making process. These models include those based on heuristics, such as a “take-the-best” heuristic, and others based on probabilistic inference, such as naïve Bayesian inferences. Unfortunately, choice probabilities are often not sufficient to distinguish among these models. In the current work, we will describe how Systems Factorial Technology (SFT) can be applied to discriminate among candidate decision-making models under different learning environments, that either encourage inference making using a subset of cues or using all cues. Systems Factorial Technology is a framework of nonparametric measures to characterize information processing from multiple sources of information using response times. In our task, participants made probabilistic inferences comparing two bugs on their poisonousness, based on the bugs physical characteristics. We present results from two conditions: (a) the strategy-imposed condition, in which participants are instructed to use specific heuristics, which served to validate the SFT methodology in detecting the underlying decision-making strategies; (b) the open-strategy condition, in which participants formed their own decision strategy. Overall, the results highlight the importance of the SFT application in diagnosing the underlying properties of decision making, which can be used as a model validation tool.
- The effects of categorization and decision-making of Lorks and Adoks
    - Authors:
        - Elena Koretsky
        - Juanita Guadalajara
        - Sabrina Esparza
        - Prof. Joe Houpt
    - Abstract: The perception of human facial features closely relates to social categorization processes. In particular, the combination of certain facial features has been found to shape observer perception of friendliness and hostility—a crucial social task. Additional decisions based on facial feature categorization, such as identifying race, gender, and age, also have important social implications. Towsend et al. (2000), and, more recently, Wang and Busemeyer (2016), demonstrated that when making decisions about group membership and hostility from facial information, many decision-makers demonstrated non-contextuality. In those experiments, the

non-informative features of the face were fixed. However, extensive face research has indicated that facial features are usually not perceived independently. The goal of our research was to investigate whether varying non-informative facial features would influence the compatibility of a group membership and individual hostility decision. Our study utilized faces of different skin tones and textures, genders, and ages, but followed the previous studies in basing the participant's task solely on the face width and lip thickness. The additional variation did not lead to different patterns of contextuality, despite the fact that they likely influenced the perception of the features. In future research, we plan to explore this decision process through the lens of systems factorial technology to examine how the process of combining information is influenced by these factors.

- A structure-sensitive alternative to Hick's Law
    - Authors:
        - Ronaldo Vigo
        - Jay Wimsatt
        - Charles Doan
    - Abstract: Hick's law aims to predict the time that people take to make a decision when presented with a set of possible choices: roughly speaking, according to the law, decision time is a logarithmic function of the number of choices. However, the evidence suggests that the law is not as effective when used to predict reaction times involving structured sets of alternatives (Vigo, 2014; Vigo & Doan, 2014). In this talk, we give theoretical and empirical justification for a more general and robust law -- derived by Vigo (2014) from the law of invariance for human conceptual behavior -- that can more precisely account for decision reaction times on structured sets. Furthermore, we argue that Hick's Law is a special case of this more general law of choice reaction times.
- Modelling the distraction task using the LBA and neural covariates
    - Authors:
        - Reilly Innes
        - Dr. Scott Brown
        - Prof. Juanita Todd
    - Abstract: Our ability to focus on a task whilst remaining sensitive to unexpected changes in the environment is vital to goal-directed behaviour. The distraction task has been widely used in cognitive neurosciences, especially in people with schizophrenia, to study performance impairments when the environment changes. In the distraction paradigm, participants perform an active task requiring simple responses while task-irrelevant changes occur occasionally. In the current study, the distraction paradigm featured a simple auditory tone duration judgment task with occasional (irrelevant) changes in the tone frequency. In the original study (Schroger & Wolff, 1998) these 'deviant' trials were associated with a distraction effect (slower and more error-prone responding). Simultaneous EEG recording of event-related responses to the sequence of tones has linked the distraction effect to key response components known as the mismatch-negativity (MMN) occurring ~150ms after the deviance onset and the subsequent P300 peaking around 250-350ms. In the present study, we compared several evidence accumulation models of behavioural response

times in the distraction paradigm. These linear ballistic accumulator (LBA) models could vary across threshold and drift rates for a variety of conditional combinations. Following this we incorporated EEG recordings to inform the drift rate parameter in a directed joint model approach. As expected, the free model provided the best descriptive adequacy of the data, however, the directed model did capture variance in the data. This is promising as the directed model allows EEG measurements to inform the model by linking latent variables to observable phenomenon.

- Informing computational models of perceptual and risky decision making with EEG and individual differences
    - Authors:
        - Joe Johnson
        - Robin D. Thomas
        - Lauren Davidson
        - Allan Collins
        - Elizabeth Pettit
    - Abstract: We use hierarchical estimation of a drift diffusion model (HDDM) in conjunction with neural data (EEG) and individual differences to understand and compare perceptual and value-based choice. For perceptual decisions, participants selected the more horizontally-oriented grating among a pair, with orientations across pairs designed to produce easy vs. difficult trials. For value-based choice, participants selected their preference among pairs of gambles with two equiprobable outcomes. Gamble pairs had equal expected values but different outcome ranges (risk), and we varied the difference between their ranges to produce similar vs. different levels of risk. We collected EEG data throughout both tasks and calculated a variety of frequency-based (N200, CPP) and time-based (parietal theta, gamma) measures to serve as continuous regressors in determining the HDDM model parameters. Finally, participants self-reported individual difference variables on decision-making styles, impulsivity, and personality. We present results that show the effects of task type, stimulus condition, and EEG signals on model parameters, such as lower drift rates for more difficult perceptual tasks and more similar risk levels. We also provide correlations between individually-estimated model parameters and relevant individual difference measures, such as lower thresholds for more intuitive decision makers. In total, we deploy a unique collection of behavioral tasks, physiological data, psychometric variables, and computational modeling to better understand decision processes.
- Assessing the 'paradox' of converging evidence by modeling the joint distribution of individual differences
    - Authors:
        - Daniel Heck
    - Abstract: Davis-Stober and Regenwetter (2019; D&R) showed that even if all predictions of a theory hold in separate experiments, not even a single individual may

be described by all predictions jointly. To illustrate this 'paradox' of converging evidence, D&R derived upper and lower bounds on the proportion of individuals for whom all predictions of a theory hold. These bounds reflect extreme positive and negative stochastic dependence of individual differences across predictions. However, psychological theories often make more specific and plausible assumptions, such as that true individual differences are independent or show a certain degree of consistency (e.g., due to a common underlying trait). Based on this psychometric perspective, I extend D&R's conceptual framework by developing a multivariate normal model of individual effects. The model mitigates the 'paradox' of converging evidence even though it does not resolve it. Overall, scholars can improve the scope of their theories by assuming that individual effects are highly correlated across predictions.

- Modeling response heaping behavior with mixture models: The effect of the anchor presentation on slider scales
    - Authors:
        - Ms. Yui Furukawa
        - Mr. Daiki Hojo
        - Mr. Jiro Sakamoto
        - Dr. Kota Takaoka
    - Abstract: In the survey design, various options in constructing the survey screen may influence the response behavior. When survey designers use slider scales, one of the options is whether or not to present anchors. It is said that adding numerical feedback to the slider scales can lead to response heaping, in which ratings are concentrated in round numbers such as 5 or 10. One explanation for response heaping behavior by Furukawa et al. (2021) considered the possibility of satisficing via response granularity. They attempted to examine the individual differences of response granularity by modeling with mixture models. This study aimed to examine the individual differences in the impact of the anchor presentation on response heaping behavior by modeling the data taken on the 0-100 slider scale with presenting five-increments anchors. We used the same mixture models as the previous study, which assumed that respondents would not necessarily rate subjective quantities in response granularity of 0-100, but rather in coarser levels of response granularity, such as 11 increments (rating in multiples of 10) or five increments (rating in multiples of 25). As a result, we could quantitatively evaluate the individual differences in response granularity as in the previous study. We also found that more respondents were likely to rate in five increments than in the previous study. The results suggest that presenting five-increment anchors may have affected individuals' response granularity to the subjective quantity, thereby leading to differences in response heaping behavior.
- A hidden Markov switching process captures dynamic effects of time-on-task in decision making.
    - Authors:
        - Guy Hawkins
        - Dr. Scott Brown
        - Dr. David Gunawan

        - Dr. Minh-Ngoc Tran
        - Dr. Robert Kohn
    - Abstract: Many psychological experiments have participants repeat a simple task. This repetition is often necessary in order to gain the statistical precision required to answer questions about quantitative theories of the psychological processes underlying performance. In such experiments, time-on-task can have important and sizable effects on performance, changing the psychological processes under investigation in interesting ways. These changes are often ignored, and the underlying process is treated as static. We propose modern statistical approaches that are based on recent advances in particle Markov chain Monte Carlo (MCMC) to extend a static model of decision-making to account for time-varying changes in a psychologically plausible manner. Using data from three highly-cited experiments we show that there are changes in performance with time-on-task, and that these changes vary substantially over individuals -- both in magnitude and direction. Model-based analysis reveals how different cognitive processes contribute to the observed changes. We find strong evidence in favor of a Markov switching process for the time-based evolution of individual subjects' model parameters. This embodies the psychological theory that participants switch in and out of different cognitive states during the experiment. The central idea of our approach can be applied quite generally to quantitative psychological theories, beyond the model that we investigate and the experimental data that we use.
- Judgment or recall: On the problematic procedure for estimating parameters in exemplar models of quantitative judgment
    - Authors:
        - David Izydorczyk
        - Prof. Arndt Bröder
    - Abstract: Exemplar models are often used in research on multiple-cue judgments to describe the underlying process of participant’s responses. In these experiments, participants are repeatedly presented with the same exemplars (e.g., poisonous bugs) and instructed to memorize these exemplars and their corresponding criterion values (e.g., the toxicity of a bug). We propose that by using this experimental paradigm the judgments of participants in a multiple-cue judgment experiment are a mixture of two qualitatively distinct cognitive processes: judgment and recall. When participants are presented with one of the trained exemplars in some later block of the experiment, they either have learned the exemplar and its respective criterion value and are thus able to recall the exact value, or they have not learned it and thus have to judge its criterion value, as if it was a new stimulus. However, the analysis procedure and the models usually applied do not differentiate between these processes and the data generated by them. We therefore investigated the effect of disregarding the distinction between these two processes on the parameter recovery and the model fit of one exemplar model. The results of a computer simulation and the reanalysis of five experiments show that the current combination of experimental design and modelling procedure can lead to extremely bias in parameter estimates and thus impaired validity of these parameters, as well as negatively affect the fit and

predictive performance of the model. As a remedy, we present a latent-mixture extension of the original model which solves these issues.

- The overweighting of extreme events in reinforcement-learning leads to frame-dependent risk preferences
    - Authors:
        - Kevin Da Silva Castanheira
        - Doug Dong
        - Dr. Ross Otto
    - Abstract: A large body of work reveals that in decision-making from experience, our risk preferences are sensitive to both decision frames (i.e., losses vs gains) and the decision context (i.e., other available options). However, the specific mechanisms underlying our frame-dependent risk preferences remain unclear. One influential account posits that the relative overweighting of extreme events leads to frame-dependent risk preferences—known as the extreme-outcome rule. However, this mechanism has yet to be formalized computationally. Critically, current reinforcement-learning models, like the delta rule, rely on learning the expected outcome of options while remaining agnostic to decision-frames. Recent work has begun to address this gap by incorporating learned reference points (i.e. the overall expected outcome) to which individual events are compared. Here, we extend these models by overweighting the influence of extreme events (i.e. surprising outcomes relative to the reference point) on learning. Simulating choice behavior in well-characterized decision-making from experience paradigms, we show that the context model, but not the delta rule, can capture the framing effect. Evaluating model fits on participant data, we show the context model outperforms the classic delta rule model. We further probed whether this context model could capture risk-preferences in a number of other decision-scenarios (i.e., gains only, losses only). Together, our results suggest that the learned reference point and the relative overweighting of extreme events can predict the frame-dependent risk preferences often seen in decisions from experience and offers a computational formalization of the extreme-outcome rule.
- Efficient selection between hierarchical cognitive models: cross-validation with Variational Bayes
    - Authors:
        - Mr. Hung Dao
        - Dr. Robert Kohn
        - Dr. Scott Brown
        - Guy Hawkins
        - Dr. Minh-Ngoc Tran
        - Dr. David Gunawan
    - Abstract: Model comparison is the cornerstone of theoretical progress in psychological research. Common practice overwhelmingly relies on tools that evaluate competing models by balancing in-sample descriptive adequacy against model flexibility, with modern approaches advocating the use of marginal likelihood for hierarchical cognitive models. Cross-validation is another popular approach but its

implementation has remained out of reach for cognitive models evaluated in a Bayesian hierarchical framework, with the major hurdle being prohibitive computational cost. To address this issue, we develop novel algorithms that make Variational Bayes (VB) inference for hierarchical models feasible and computationally efficient for complex cognitive models of substantive theoretical interest. It is well known that VB produces good estimates of the first moments of the parameters which gives good predictive densities estimates. We thus develop a novel VB algorithm with Bayesian prediction as a tool to perform model comparison by cross-validation, which we refer to as CVVB. In particular, the CVVB can be used as a model screening device that quickly identifies bad models. We demonstrate the utility of CVVB by revisiting a classic question in decision making research: what latent components of processing drive the ubiquitous speed-accuracy trade-off? We demonstrate that CVVB strongly agrees with model comparison via marginal likelihood yet achieves the outcome in much less time. Our approach brings cross-validation within reach of theoretically important psychological models, and makes it feasible to compare much larger families of hierarchically specified cognitive models than has previously been possible.

- Probabilistic free price promotion vs. sure price promotion: Comparison between Japan and the U.S.
    - Authors:
        - Mr. Masakazu Ando
        - Koji Kosugi
    - Abstract: Mazer, Shampanier, and Ariely (2017) called a probabilistic free price promotion a promotion in which the purchase amount is free through a lottery. On the other hand, a promotion that ensures a lower purchase price was called a sure price promotion. Probabilistic free price promotions are known to have higher selection rates and sales than sure price promotions with equal expected values (Mazer et al., 2017; Lee, Morewedge, Hochman, and Ariely, 2019). In Experiment 4 of Mazer et al. (2017), they investigated whether participants would choose a probabilistic or sure price promotion when the amount was controlled and the probability was varied. The study also examined how the selection rate differed among the four other conditions of the promotion: pen, Amazon gift certificate, monetary gain, and monetary loss. The results showed that the promotion condition tended to pursue more risk than the monetary gain condition, even though the expected values were equal. This suggests that people have different risk tolerance depending on what they are willing to pay for. However, we conducted a similar survey in Japan and found a different trend from the previous studies, which we report here.
- Modeling error correction in a self-paced periodic tapping task
    - Authors:
        - Mr. Pierre Gianferrara
        - Shawn Betts
        - Dr. John Anderson
    - Abstract: This talk is concerned with the implementation of period error correction in the adaptive control of thought - rational (ACT-R) architecture as part of a novel periodic tapping motor extension. Past sensorimotor synchronization models have

often implemented error correction via joint phase and period correction mechanisms in the context of synchronization-continuation paradigms (Repp, 2005). Unlike past work, our goal was to model error correction in a self-paced tapping task with discrete feedback. To do so, we designed a new experiment named ChemLab in which players filled rows of 8 beakers by pressing the space bar periodically. In this task, feedback was provided both visually and auditorily. Specifically, taps that were too fast triggered a high-pitched sound and turned on a red light on the screen. Conversely, taps that were too slow triggered a low-pitched sound and turned on a blue light on the screen. We assessed periodic tapping in 4 non-overlapping temporal intervals between 200 and 1,200 ms. For each row of beakers, the temporal interval was set to switch once between the 3rd and the 5th beaker, such that participants either needed to speed up or slow down. In this talk, we show how period correction can be modeled in ACT-R with productions implementing feedback perceptual processing, and a basic motor error correction mechanism. We conclude by showing that modeling error correction in periodic tapping tasks with discrete feedback requires one to capture task-specific elements of feedback in addition to more general motor mechanisms.

- Do people use all information when making decisions with an automated aid? An application of Systems Factorial Technology
    - Authors:
        - Cara Kneeland
        - Prof. Joe Houpt
    - Abstract: Imperfect automation aids can lead to many negative consequences. To help mitigate those consequences, researchers have suggested that users be more vigilant, and particularly use multiple sources of information when making a decision with an automated aid. Prior research has suggested that people may still rely solely on the aid even when provided with other sources of information, but this research has tended to rely on strong assumptions and may have confounds. To test whether participants are using all or only one source of information when provided with an automated aid with more robust methods, we examined automation usage with Survivor Interaction Contrast from the Systems Factorial Technology framework. Additionally, we tested whether performance incentives and early experience with automation failures during training encourages more exhaustive processing. Participants completed a speeded length judgment task where they were provided with a reliable but imperfect aid to assist them in their decision. We found that across all conditions, participants used a serial, first-terminating process, supporting the view that participants use only one source of information. However, results from a logistic regression suggest that participants are likely using both the automated aid and the signal across all trials instead of relying solely on one. Implications of this research highlight a different strategy where participants may be alternating what source of information they use, which may be beneficial when using an imperfect aid in speeded decisions. This research can inform interface designs that support effective strategies for making speeded decisions with an automated aid
- Investigating metacognitive sensitivity of tip-of-the-tongue states and feeling-of-knowing judgments with general recognition theory

- Authors:
  - Mr. Ali Pournaghdali
  - Bennett L. Schwartz
  - Fabian Soto
- Abstract: Tip-of-the-tongue states (TOT) and feeling-of-knowing judgments (FOK) are metacognitive experiences about the possibility of future retrieval of information when recall fails. Many studies show that experiencing a TOT or a high FOK increases the possibility of correct retrieval of missing information, which demonstrates metacognitive sensitivity (see Schwartz & Pournaghdali, 2021). However, evidence for metacognitive sensitivity of TOT and FOK mainly derives from measures that conflate metacognitive sensitivity with metacognitive bias. In the current study, we used general recognition theory (GRT) to provide bias-free assessments of metacognitive sensitivity for TOT and FOK. We asked participants to answer general-knowledge questions. If recall failed, participants provided metacognitive judgments of TOT and FOK, memory recognition responses, and metacognitive judgements of confidence on those recognition responses. After collecting the behavioral data, we fit two different GRT models to the data to assess metacognitive sensitivity of TOT and FOK. Using estimated parameters of the models, we constructed two sensitivity vs. metacognition (SvM) curves, which represent sensitivity in the recognition task, as a function of strength of metacognitive experiences: an SvM curve for TOT and an SvM curve for FOK. According to both SvM analyses, the highest level of recognition sensitivity was accompanied with highest strength of metacognitive experiences, and as the magnitude of metacognitive experiences dropped, so did recognition sensitivity. However, the recognition sensitivity was higher than chance level when people did not experience a TOT or FOK. These results are the first bias-free indication of metacognitive sensitivity of TOT and FOK judgments.

- Interactions between symptoms of depression, stress, and anxiety in university students: A network analysis
  - Authors:
    - Dr. Alfonso Díaz Furlong
    - Ms. Berenice López López Ventura
    - Dr. Reyna Xoxocotzi Xoxocotzi Aguilar
    - Dr. Alfonso Díaz Cárdenas
  - Abstract: The psychological processes of depression, stress, and anxiety have traditionally been measured by indicators and analyzed by dimensional reduction methods (e.g. exploratory factor analysis). Due to some limitations on the results obtained by the classical methods, we considered a Network Analysis approach. In this setup, the symptoms form a complex dynamical system with interactions among them. The symptoms could mediate, moderate, increase, or decrease other symptoms. In this study, we built the symptom networks to analyze the interactions of the factors of the depression, anxiety, and stress processes in a sample of university students. We used a Network Analysis in JASP to estimate the network structure of DASS21 symptoms (Depression, Anxiety Stress Scale) evaluated in 174 university students from the Benemérita Universidad Autónoma de Puebla, Mexico. We built

the networks through the Graphic Gaussian Model to discriminate edges and we selected the lowest EBIC model. We measured the indices of centrality, cluster, strength, closeness, and intermediates. We present the results for students of different areas of knowledge and the corresponding gender networks. Based on the results, appropriate intervention programs could be constructed for the particular symptoms shown in the different groups of participants.

- Modeling the response to trauma: accumulation of and accommodation to child sexual abuse
    - Authors:
        - Mr. Jiro Sakamoto
        - Dr. Kazunori Tobisawa
        - Ms. Yui Furukawa
        - Dr. Kota Takaoka
    - Abstract: Child sexual abuse (CSA) often lasts for more than a few years. Various kinds of clinical symptoms appear in CSA victims, depending on the persistent damage. Trauma response such as problematic sexual behavior is a highly specific feature in CSA victims. Nevertheless, it remains unclear how the developmental status of a child relates to the trauma response resulting from CSA. The aim of this study was to (□) describe accumulation of and accommodation to CSA effect in relation to age and the duration of victimization, (□) estimate the developmental transition of inhibition function, and (□) predict the trauma response via a computational conflict model regarding CSA effect and inhibition function. The data was collected by the national survey in Japan (December 2020). Four hundred ninety-two CSA cases were met the inclusion criteria. The proposed model was implemented in Stan. All chains were well mixed and converged. The results indicated that (□) the impact of CSA on trauma response was cumulative over the duration of victimization, (□) the magnitude of the cumulative added impact was inversely proportional to the duration of victimization, (□) developmental transitions of inhibition function varied with the trauma responses, and (□) some types of trauma response might be observed only at a particular age and only for a specific duration of victimization. The proposed conflict model regarding clinical outcomes will be widely applicable and give us interpretable predictions.
- Attractiveness effects on search: Validating an iCodes parameter
    - Authors:
        - Sophie Scharf
        - Dr. Marc Jekel
        - Prof. Andreas Glöckner
    - Abstract: The integrated coherence-based decisions and search model (iCodes) predicts that participants show a tendency to search for information on the option currently supported by the already available evidence, a prediction coined as the attraction search effect. While this search tendency could be shown to be robust, the data also showed considerable interindividual variability in the attraction search effect. One explanation could be that the relative strength of the attractiveness influence on search varies between situations and participants. Within iCodes, the relative strength of option attractiveness on the information-search process is

represented by the γ parameter. In this project we experimentally manipulated between-subjects participants' awareness of differences in attractiveness of the choice options by asking the experimental group to rate option attractiveness before search. Indeed, rating options' attractiveness increased the tendency to search for the more attractive option compared to not rating options' attractiveness. The effect of these ratings was further reflected in individually fitted γ parameters: Parameter values of participants who rated option attractiveness showed that their search was influenced more strongly by attractiveness than participants in the control group. The results of this project corroborate the role of the γ parameter and that iCodes is able to capture the effect of a theoretically-motivated manipulation of information-search behavior. Thus, this project further validates the assumed information search process and emphasizes the role of the already available evidence in information search but also takes systematic differences in the size of the effect into account.

- When alternative hypotheses shape your beliefs: Context effects in probability judgments
    - Authors:
        - Xiaohong Cai
        - Tim Pleskac
    - Abstract: When people are asked to estimate the probability an event will occur, they could make different subjective probability (SP) judgments for different descriptions of the same event. This implies the evidence or support recruit to make SPs is based on the descriptions or hypotheses instead of the events. To capture this violation of description invariance descriptive theories like support theory often make a different invariance assumption: the support assigned to a hypothesis is invariant to the hypotheses it is being considered with. Here we examined the support invariance assumption across two studies where participants were asked to estimate the probability with a verbal scale or a numeric scale that a target bicyclist would win a race. The first study shows that the presence of a distractor—a bicyclist that is objectively dominated by the target— boosts the SP assigned to the target hypothesis with a verbal scale compared to when no distractor is present. The second study shows that the presence of a resembler -a bicyclist that is objectively similar to the target- differentially detracts from the SP assigned to the target regardless of the type of scale. These context effects invalidate the regularity and the strong independence assumptions of support theory. This invalidation suggests that the support people recruit about the target hypothesis also depends on the other hypotheses (bicyclists) which are under consideration.
- Dimension reduction approaches to modelling many attribute choice
    - Authors:
        - Mr. Gavin Cooper
        - Guy Hawkins
    - Abstract: I have previously applied evidence accumulation models to discriminate between which decision strategies are used by participants making multi-attribute choices about products. One limitation of this work is that it has currently been applied only to choices with 2 attributes. A natural extension of this work is to move towards a higher number of attributes or options, however model complexity increases exponentially with attributes x options when assessing strategies. I will

present an approach currently being undertaken that asks participants to assess pairs of options (phones) differing across 5 attributes. The participants are asked to make two different judgements of each pair of phones, a preference judgement and a similarity judgement. The preference component of the experiment simply asks participants which phone of each pair they would choose. The similarity judgements are over the same set of phone pairs and participants rate each pair on a 7 point scale from low to high similarity. An initial analysis using multi-dimensional scaling on the similarity data (both average similarity and individual ratings) shows the phones are well represented by two dimensions. The plan will be to take each individuals multi-dimensional scaling solution and use that as input to a cognitive model of the preferences. This model will be contrasted to approaches where option utilities are derived from multi-attribute utility theory to see which better explains preferences.

- Computationally rational strategies for integrating reinforcement learning and working memory in younger and older adults
    - Authors:
        - Dr. Cindy Lustig
        - Hyesue Jang
        - Dr. Richard Lewis
    - Abstract: We investigate the possibility that adult age differences in a choice learning task can be explained by adaptations to age differences in the limits ("bounds") of different components of learning and memory. Learning which choice option is most likely to lead to reward involves both conscious, effortful working memory (WM) and automatic, implicit reinforcement learning (RL) processes (Collins 2018; Collins & Frank, 2018). WM and RL have complementary strengths and weaknesses (WM: fast/accurate but capacity-limited/delay-sensitive; RL: robust but slow). Optimal performance depends on finding the right balance between these systems, based on their relative effectiveness. WM declines more than RL with age, and thus the theoretical concept of bounded optimality (Lewis et al., 2014) predicts that older adults will rely more on RL than WM during the choice-learning task than will young adults. We will explore how a modified version of an existing computational model (Collins & Frank, 2018) might explain individual differences in the performance of young and older adults by deriving the optimal balance between these systems depending on their limitations.
- Testing sample-based accounts of probability judgments using a ranking task
    - Authors:
        - Xiaotong Liu
        - Dr. Henrik Singmann
        - Prof. Arndt Bröder
    - Abstract: People's explicit probability judgements often appear to be probabilistically incoherent. The most prominent example of this is the conjunction fallacy (Kahneman & Tversky, 1983). Recently, a growing body of research argues that biases in probability judgements can arise from rational reasoning processes based on mental samples from coherent probability distributions. However, the sample-based normative accounts of probability judgements are mainly investigated in probability estimation tasks. In the current study, a ranking task is used to study people's explicit

probability judgements, and more importantly, to test the sample-based normative accounts of probability judgements. In the ranking task, participants are asked to rank four events, A, not-A, B, and not-B, according to their perceived likelihoods of occurrence. Results show a novel probabilistic reasoning bias: Participants often provide logically impossible rankings, violating the complement rule and the transitive rule. Interestingly, one existing sample-based normative account, namely the Probability Theory plus Noise (PT+N) account (Costello & Watts, 2014), can potentially explain the logical inconsistencies in rankings of events. We formally derive the predictions for rankings from the PT+N account. Our predictions suggest that specific qualitative patterns should appear in people's responses if the logically impossible rankings are solely the products of internal sampling processes instead of inconsistent inherent beliefs.

- Conjoint features and inductive category learning
    - Authors:
        - Matt Wetzel
        - Dr. Kenneth J Kurtz Kurtz
    - Abstract: In the traditional artificial classification learning paradigm, each training item is typically a single object composed of values along particular object features (e.g., shape, size, shading, length of tail, etc). We investigate an alternative framework for inductive category learning in which stimuli consist of pairs of items and the diagnostic basis for classification is conjoint features: properties of the stimulus that arise from a relative evaluation of the traditional dimension values of the items in the pair. For example, if a pair consisted of a small white circle and a large black circle, the identity match between the items on the shape dimension would be a conjoint feature that might predict the category label. Under what conditions can people learn categories based on such features? Further, to what extent does this ability reflect common or distinct machinery relative to traditional inductive category learning? In a series of experiments, we trained subjects to categorize stimuli consisting of two fish that each varied along one traditional dimension: length of body. Fish pairs of similar length belonged to one category while fish pairs of different lengths belonged to the other. We found that subjects appeared to successfully leverage the conjoint feature based on the relative comparison of alignable stimulus feature values (body length). Further, we tested generalization performance for novel items (previously unseen pairs) and found evidence of both graded and non-graded generalization gradients depending on the category structure that was observed during training. We propose a modeling approach to account for these results in terms of neural networks that incorporate a design principle of simple preprocessing layers to recode the input in terms of pairwise hypotheses such as ‘same-value.’

Wednesday mixer

- Start time: 18:00 EDT Jul 07, 2021
- End time: 19:00 EDT Jul 07, 2021

Friday mixer

- Start time: 12:00 EDT Jul 09, 2021
- End time: 13:00 EDT Jul 09, 2021