# Curiosity, Information Seeking, & Exploration

## From Neurons to Cognition

## September 30 – October 1 2025

Brown University

https://ciseconf.github.io/CISE_2025/

# Contents

# Schedule of Events

## DAY 1 – Tuesday, September 30

- 10:00 – 10:45 | **Registration** Check-in and coffee (*Pembroke*)
- 10:45 – 11:00 | **Opening Remarks** Romy Frömer (*Pembroke*)
- 11:00 – 12:00 | **Session 1** (*Pembroke*)
    - **Short Talks:** Ohad Dan, Hayley Dorfman, Jo Cutler
    - **Invited Talk:** Tali Sharot
- 12:00 – 12:15 | **Poster Blitz Talks:** Lou Marie Haux, Madeline Klotz, Mrugsen Gopnarayan (*Pembroke*)
- 12:15 – 1:15 | **Lunch Break** (*Sayles*)
- 1:15 – 2:45 | **Poster Session I** (*Sayles*)
- 2:45 – 3:45 | **Session 2** (*Pembroke*)
    - **Invited Talks:** Valeria González, Russell Golman
- 3:45 – 4:15 | **Coffee Break** (*Pembroke*)
- 4:15 – 6:00 | **Session 3** (*Pembroke*)
    - **Contributed Talks:** Ethan Bromberg-Martin, Kara Kedrick, Keyu Hu
    - **Invited Talks:** Kate Nussenbaum & Haoxue Fan
- 7:30 – Late | **Social Meet-Up** (*The Hot Club, Providence*)

# Schedule of Events

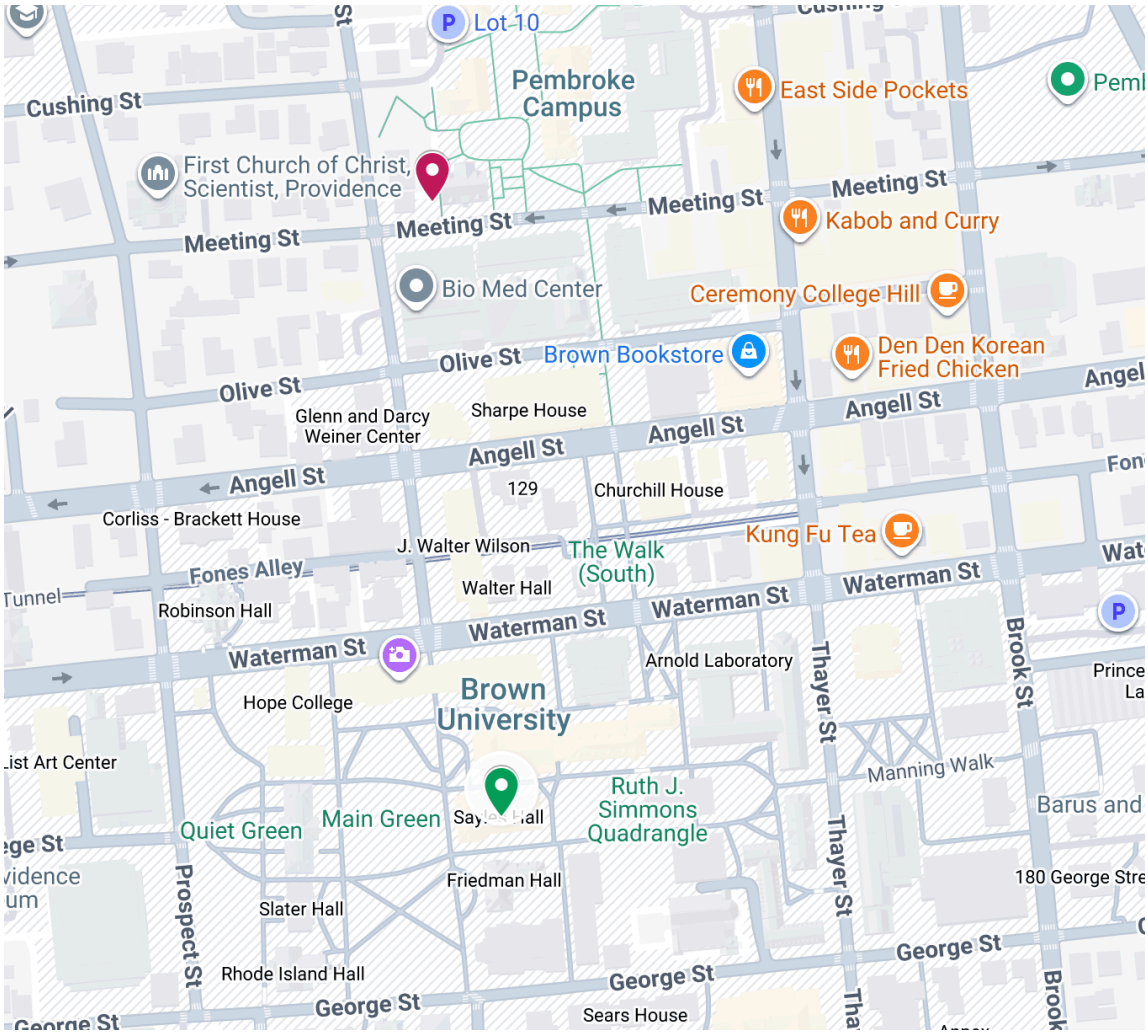
## DAY 2 – Wednesday, October 1

- 09:00 – 10:30 | **Session 1** (*Pembroke*)
  - **Invited Talks:** George Loewenstein, Alireza Modirshanechi
  - **Contributed Talks:** Elizabeth Lapidow, Jordan Wylie
- 10:30 – 11:00 | **Coffee Break** (*Pembroke*)
- 11:00 – 11:45 | **Session 2** (*Pembroke*)
  - **Invited Talk:** Caroline Charpentier
  - **Contributed Talk:** Jennifer Bussell
- 11:45 – 12:15 | **Poster Blitz Talks:** Hanbo Xie, Andra Geana, Alexandra Nicholson-Brown, Sienna Bruinsma, Jordan Deakin, Alice Xia (*Pembroke*)
- 12:15 – 1:15 | **Lunch Break** (*Sayles*)
- 1:15 – 2:45 | **Poster Session II** (*Sayles*)
- 2:45 – 3:45 | **Session 3** (*Pembroke*)
  - **Invited Talks:** Jacqueline Gottlieb, Robert Wilson
- 3:45 – 4:00 | Closing Remarks

# Locations

Map of Brown University showing location of:

- Pembroke Hall (in red)
  - Talks and Coffee Breaks
- Sayles Hall (in green)
  - Lunch and Poster Sessions



# About CISE conference

Curiosity, information seeking, and exploration (CISE) are central aspects of cognition, driving learning, decision-making, and creativity. Although this has long been recognized, how we seek information has only recently become a topic of scientific research. Recent advances in experimental design, modelling, and generative AI present a unique opportunity to address fundamental questions about the mechanisms and dynamics of information-seeking behavior. Now, the field is expanding rapidly across fields including psychology, neuroscience, ecology, economics, and computer science.

The CISE conference aims to establish a community of researchers at the cutting edge of developments in a range of approaches to understanding curiosity, information seeking and exploration. This event will bring together interdisciplinary researchers through talks and poster presentations, to catalyze knowledge exchange and integration across disciplines.

# Organizing Committee

Romy Froemer
University of Birmingham

Jo Cutler
University of Birmingham

Ohad Dan
Yale University

Hayley Dorfman
Harvard University

Matt Nassar
Brown University

Jacqueline Gottlieb
Columbia University

Tali Sharot
UCL / MIT

# Participant Information

## Wi-Fi access

- Guests requiring Wi-Fi access can either:
    - Connect to the Brown-Guest wireless network
    - Connect using Eduroam wireless network if they are from an Eduroam member institution
- If you have a Brown username, we recommend connecting to Brown instead

## Traveling by Car and Parking

- Visitor parking
    - Suggested parking is available at Lot 57, located at 75 Charlesfield Street – approximately 10-15 minutes walk from Pembroke Hall and 10 minutes from Sayles Hall
- ADA Visitor Parking: Brown maintains visitor spaces that meet ADA standards for accessibility in Lot 65, which is located on the south side of Benevolent Street between Thayer and Brook Streets. Any valid state ADA placard may be used in any ADA spaces in the lot to park for FREE.
- Street Parking: Visitors may find metered parking on the streets in and around campus. Metered parking costs 25 cents for every 12 minutes. Metered spaces allow for maximum 2-hour parking.
- Please pay close attention to on-street signs marked for Brown specific spaces. These spaces are reserved for Brown employees until noon and require a specific Brown daytime employee parking permit. Visitors can park in these spaces after noon. Cars parked in these spaces before noon without Brown employee parking permits may be tickets and/or towed at the owner's expense.

- **Download Passport Parking App:** Download the Passport Parking mobile app before traveling to Brown so you can pay for metered parking in Providence, if necessary. This app has replaced use of credit cards at paid parking meters in the city. This includes on major streets such as Waterman, Angell and Hope, and on numerous streets in the Jewelry District, where Brown does not have a designated visitor's lot (although there are parking garages that accept visitors at the garage's hourly and daily rates).

## Traveling by Air

- Greater Providence's T.F. Green Airport (PVD) is 10 miles (15 minutes) south of Brown. Options include taxi, rideshare, or RIPTA bus route 20. Rental cars are also available.
- Boston Logan International Airport is about an hour's drive from campus.

## Traveling by Train

- From Boston, take a direct train from Boston's South Station to Providence Station using either the MBTA Commuter Rail (ca 1h 10 min, $12.25) or the Amtrak (ca 40 min, from $5 to $45). From Providence Amtrak station, Brown University is a 10-minute drive by taxi, rideshare or bus.

## Walking to campus

- Walking from Providence Amtrak station takes 15-20 minutes. The route passes through downtown Providence with plenty of sights along the way.

# Keynote Speakers

## TALI SHAROT (UCL / MIT)

**Building Efficient & Useful Knowledge Systems:** How do people decide what they want to know? Human knowledge can be conceptualized as a network of interconnected concepts. An advantageous knowledge network will facilitate both coherent categorization and creative cross-domain inferences that facilitate innovation. Such efficiency is achieved when local clustering is balanced with long-range shortcuts—an architecture known as a small-world structure. We find that humans intuitively value information based on its ability to optimize such efficiency of knowledge organization (interestingly LLMs show similar tendencies). They combine this evaluation with two other key assessments of information - its usefulness in guiding action and its emotional impact - to guide information seeking. These three factors can be distilled into two fundamental components of value: extrinsic and intrinsic. Our findings reveal that these two components are represented by distinct brain systems, with the traditional reward system (e.g., VMPFC, striatum) selectively encoding intrinsic value. Finally, we introduce a novel tool that leverages language analysis algorithms to evaluate and score information based on its usefulness, emotional valence, and ability to enhance understanding. These scores are displayed alongside web search results, guiding users toward content that best fulfills their needs. Together, these findings reveal an adaptive prioritization of humans toward information that optimizes the different functions of the knowledge system.

## VALERIA GONZALEZ (REED COLLEGE)

**The neural basis of information-seeking and the power of individual differences:** Animals often make choices to gain information, even when the information cannot be used to change the outcome. In our research, rats could choose between an uninformative option followed by a cue that predicted reward 50% of the time versus a fully informative option that signaled outcomes with certainty but was rewarded only 20% of the time. We found that chemogenetic inhibition of the anterior cingulate cortex (ACC), but not the orbitofrontal cortex, basolateral amygdala, and dorsomedial striatum, is important for evaluating options involving reward-predictive information. Furthermore, optical inhibition of the ACC suggested a causal role in supporting reward expectation to a cue signaling reward with certainty. In all those cases, the preference for information varied substantially between subjects, which we see as an opportunity, allowing us to understand the environmental factors that can contribute to this variability. Preliminary findings suggest a role of enrichment and curiosity, but not anxiety as predictors of information-seeking behaviors.

## RUSSELL GOLMAN (CARNEGIE MELLON)

**Explanation Generation: Questions Direct Exploration in Semantic Space (Kara Kedrick & Russell Golman)**

In everyday reasoning and scientific inquiry, explanations help people make sense of their experiences and observations. We investigate how people generate new possible explanations. Specifically, we study how the phrasing of "why" questions shapes exploration of the space of possible explanations. We hypothesized that semantic exploration is guided by the salience of words in a question, with salience reflected in words that appear earlier, are more surprising, or are more familiar. Participants in our experiment generated explanations in response to "why" questions comparing two words, with the order of these two comparison words randomized. Using a large language model, we measured how closely each explanation aligned with the comparison words. Results supported two of three hypotheses: explanations aligned more strongly with earlier and more familiar words. These findings highlight how phrasing of a question can shape explanation generation, demonstrating context-dependence in how people explore a conceptual space.

## KATE NUSSENBAUM (BOSTON UNIVERSITY)

**Changes in strategic exploration across development**

From childhood to adulthood, people learn through two forms of exploration: 'external' exploration, in which they take actions and learn from experienced outcomes, as well as 'internal' exploration, in which they imagine possible actions and learn from the hypothetical outcomes they could yield. In my talk, I will first discuss a recent study in which we examined how and why the selection of exploratory actions changes systematically across development. I will then highlight how the decision problem that learners face in the external world — determining whether and what to explore — extends to the internal sampling of thoughts. I will present preliminary work in adults in which we begin to characterize how learners solve this problem. I will discuss how future developmental work could reveal important parallels between external and internal exploration, and ultimately lead to a more comprehensive understanding of the development of strategic information-seeking.

## HAOXUE FAN (BROWN UNIVERSITY)

**Understanding individual differences in uncertainty-driven exploration through the lens of affective components:** Exploration is at the core of many real-life decisions, helping people gain information about the environment and make better choices in the long run. Uncertainty lies at the heart of the explore-exploit dilemma and is a double-edged sword: On one hand, people could use different kinds of uncertainty to guide exploration. On the other hand, uncertainty is associated with variable affective experiences that impacts people's ability to make adaptive decisions, which could be exaggerated in psychopathology such as anxiety. Today I am going to present a series of studies examining the relationship between affective components and uncertainty-driven exploration. I will first show that people use a hybrid of directed, random, and undirected exploration, which is sensitive to relative uncertainty, total uncertainty, and relative value respectively. I will then map out the element-wise anxiety-exploration relationship and show that trait somatic anxiety – the propensity to experience physical symptoms of anxiety – is selectively associated with decreased directed exploration. Besides trait-level factors, I will discuss another study highlighting the role of transient pupil-linked arousal in random exploration. Finally, I will present a recent study where we find behavioral signatures of directed exploration during multi-step planning, suggesting that the uncertainty-driven exploration framework can be applied to both internal and external exploration.

## GEORGE LOEWENSTEIN (CARNEGIE MELLON)

**Three Decades of Intermittent Information-gap Research**: In a 1994 review of the literature on curiosity, I proposed an account of curiosity based on the concept of an "information gap." In this talk, I will discuss different lines of research I've pursued since then that have emanated from the initial paper, including a formal model of information gaps that Russell Golman and I developed and have applied to different domains of judgment and decision making.

## ALIREZA MODIRSHANECHI (EPFL)

**Surprise and novelty in human reinforcement learning**: Human reinforcement learning involves multiple processes—e.g., exploration, model-building, and planning. "Surprise" and "novelty" are believed to play important roles in multiple of these processes, e.g., through guiding exploration or modulating the speed of learning. However, there is currently no consensus on the definition of surprise and novelty, and it remains unclear whether, for example, "surprise" as in "surprise triggers curiosity" is the same notion as the one in "surprise modulates synaptic plasticity." In this talk, I will discuss our latest results, addressing the questions "How can we dissociate signals related to surprise and novelty?" and "How do different signals contribute to human exploration?"

## CAROLINE CHARPENTIER (UNIVERSITY OF MARYLAND)

**A Bayesian belief updating account of confirmation bias during advice seeking and integration:** People often rely on advice from others when making decisions, but this process can be biased: individuals may overweigh their own beliefs and disregard the advice, or selectively favor advice that confirms their beliefs, regardless of accuracy. Although both forms of confirmation bias are commonly observed, their cognitive underpinnings remain unclear. To address this gap, we introduce a novel task that measures advice-seeking and advice-integration decisions, with advisors varying in accuracy and confirmatory tendencies. Both types of decisions were jointly modeled using a Bayesian belief-updating framework, with biased variants that allowed differential weighting of prior information and confirmatory advice. The model including both biases best captured participants' behavior, revealing stronger weighting of prior beliefs over advice and sensitivity to advisors' confirmatory tendencies. Model-derived belief uncertainty and choice difficulty predicted confidence, and the influence of belief uncertainty on confidence was stronger in individuals with greater prior-weighting bias. Together, these findings offer a mechanistic account of biased belief formation - and its link to metacognitive sensitivity - across both seeking and integrating social information, with implications for understanding real-world belief rigidity in today's polarized information ecosystem.

## JACQUELINE GOTTLIEB (COLUMBIA UNIVERSITY)

**Meta-Level Control of Learning and Information Foraging in Natural Settings**: Over the past centuries, neuroscience and psychology examined behavior in highly simplified settings in which relevant information is carefully curated and given to participants by default. Natural settings, however, pose an existential problem of information selection: we must autonomously decide, based on the practically infinite set of information that confronts us, when and to what to attend, when and what to commit to memory, and when and what to learn. Our understanding of how the brain resolves these challenges and generates behaviors fueled by curiosity is in its infancy. Here, I will propose that challenges of information selection are resolved by a meta-level controller that monitors processes of attention, learning and memory and decides when and how to recruit them based on their anticipated benefits and computational costs. I will discuss a biologically plausible model that implements reinforcement meta-level control (RML) in a circuit comprising the anterior cingulate cortex and neuromodulators dopamine and norepinephrine. I will discuss the power of the model to explain empirical data (behavior and single-neuron activity) during uncertainty-based attention control, and its implications for the detection of learnability – the ability to detect learnable patterns given unlabeled mixtures of true and random associations that characterize natural settings.

## ROBERT WILSON (GEORGIA INSTITUTE OF TECHNOLOGY)

**Information and randomization in exploration and exploitation**: Many decisions involve a trade-off between exploring unknown options for information and exploiting known options for a more certain payoff. In this talk I will present evidence that people use two strategies to solve these explore-exploit dilemmas: directed exploration, driven by information, and random exploitation, driven by noise. These two strategies appear to rely on dissociable cognitive and neural processes, but I will show that they can arise from a single model based on mental simulation. This model accounts for the effects of uncertainty, time horizon, and the informativeness of feedback on directed and random exploitation as well as more recent findings suggesting that random exploitation is truly random.

# Contributed Talks

## Why did we evolve to seek information? Theory of subjective value without instrumental value

*Ethan Bromberg-Martin*
Washington University School of Medicine

**Abstract:** *Objective:* Why do we want to know the future? We can be strongly motivated to seek information about uncertain future rewards. We often seek this information even when it has no instrumental value for controlling the outcome, suggesting we endow it with subjective value of its own. There has been a recent explosion of research on this preference, called "temporal resolution of uncertainty" in economics and "observing behavior" in psychology. However, the most fundamental question remains unanswered: why? This subjective value without instrumental value seems maladaptive. Yet it is conserved across species, suggesting it evolved for a crucial purpose. Here we develop a theoretical framework to understand subjective value in light of evolution. We formulate theories that explain information's subjective value in lab experiments as an evolved estimate of its instrumental value for solving core computational problems organisms face in their natural environments. We use this framework to evaluate extant evolutionary theories of the origin of information seeking: Time Allocation theory, that information improves time allocation for foraging, and Credit Assignment theory, that information improves temporal credit assignment for learning.
*Methods:* We embody theories with models where optimal Bayesian agents maximize reward rate in naturalistic environments, and derive their instrumental value of information (IVOImodel). We measure the subjective value of non-instrumental information in our recent experimental data (SVOIexp; n=521 humans, n=4 monkeys). We compare how IVOImodel and SVOIexp are governed by a broad suite of motivational factors (expected reward, measures of reward uncertainty, information and reward timing), quantifying their effects with logistic regression.
*Results:* We show these theories value information for distinct reasons, yet remarkably, both make a series of similar, specific, correct predictions about SVOIexp. For example, every factor in our suite has matching directional effects on IVOImodel in both models, SVOIexp in humans, and SVOIexp in each monkey (n=5 factors; all $\beta$ >0.1¢ in humans, >20 ul juice in monkeys, >10 ul in models (robust to parameter variation); all $p<0.01$). We then leverage our framework to prove the theories are dissociable due to their distinct mechanisms, and derive novel factors to do so.
*Conclusion:* We present a framework for understanding the origin of subjective value. Applying it to information seeking reveals evidence that evolution managed to endow humans and animals with remarkably robust information value computations to simultaneously enhance both time allocation and credit assignment in natural environments.
**Keywords:** *D - Risk & Uncertainty; I - Valuation & Decision Making; L - Methodological Developme*

## Creative Foraging and the Explore-Exploit Trade-off in Knowledge Networks

*Kara Kedrick*[1], Kyana Burhite[2], Iris Vilares[3], and Paul R. Schrater[4,5]

[1]Institute for Complex Social Dynamics, Carnegie Mellon University [2,3,4]Department of Psychology, University of Minnesota [5]Department of Computer Science and Engineering, University of Minnesota

**Abstract:** The scope of knowledge is constantly evolving, due to such factors as environmental changes, cultural evolution, and scientific discovery. Consequently, we are frequently confronted with gaps in our knowledge, compelling us to seek information from available sources. Sometimes the information we seek is easy to find; other times it has yet to be established by others, requiring us to creatively come up with an original perspective. Yet, little is known about how our foraging strategies change depending on the ease with which the information we seek is readily available. We investigated how the need to generate new ideas influences the rate at which individuals explore or exploit existing information. Participants (N = 138) answered questions either fully answerable (low-creativity condition) or not fully answerable (high-creativity condition) with information they foraged for on Wikipedia. We created knowledge networks from the foraged information, wherein Wikipedia pages were nodes. The edges linked pairs of Wikipedia pages when they were visited by the participant either sequentially or within the same condition, and were weighted based on the semantic similarity between the pair of pages. This approach allowed us to measure exploration (jumping between disparate pages) and exploitation (viewing closely related pages). In the high-creativity condition, participants were more likely to trade-o! between exploration (lower average edge weights) and exploitation (higher average clustering coe"cients). This trade-o! was associated with responses that were more novel, diverging further from the Wikipedia text, compared to less novel responses. These findings reveal how foraging strategies di!er in creative versus non-creative contexts, and provide insight into the processes that underlie learning and scientific discovery.

**Keywords:** *creativity, information seeking, semantic networks, optimal foraging*

## Dynamic integration of dissociable value codes for reward and information in the human prefrontal cortex

*Keyu Hu*[1], Changlin Bai[1], Yi Yao[2], Haiyan Wu[1]*

[1]*Centre for Cognitive and Brain Sciences and Department of Psychology, University of Macau, Macau, China.* [2]*Department of Functional Neurosurgery, Xiamen Humanity Hospital, Fujian Medical University, Fujian, China.* *Corresponding author

**Abstract:** Balancing exploitation of known rewards with exploration for new information is a core challenge in decision neuroscience. While the prefrontal cortex is critical for this process, how its subregions dynamically cooperate to balance between exploiting known rewards and exploring for information remains unclear. Here, we recorded intracranial stereo-electroencephalography (SEEG) from epilepsy patients (N= 15, 4 females, age 22.43±3.95) performing a gambling task that orthogonally manipulated expected reward

and information gain to find the neural dynamic of the ventromedial prefrontal cortex (vmPFC) and anterior cingulate cortex (ACC) during decision. Using reinforcement learning-based computational modeling and time-frequency analyses, we identified functionally dissociable value representations: vmPFC activity encoded both reward (Peak Effect: 61 Hz, $t = 3.43$, $p < 0.01$) and information gain (Peak Effect: 57 Hz, $t = 2.95$, $p < 0.05$), while ACC activity was selectively sensitive to information gain (Peak Effect: 103 Hz, $t = 6.22$, $p < 0.001$). Crucially, integration of these value signals was governed by a dynamic, context-dependent communication protocol. During reward exploitation, heightened phase synchrony (phase-locking value, PLV) between the vmPFC and ACC predicted choices for high-value options ($\beta$reward = 0.45, $t = 2.28$, $p < 0.05$). Conversely, when subjects faced a direct explore-exploit trade-off, this synchrony was replaced by a stronger, directed information flow from vmPFC to ACC, as measured by the phase slope index (PSI; $t = 2.81$, $p < 0.01$). This directional signal predicted choices toward information-rich, lower-reward options ($\beta$info = 1.82, $t = 3.11$, $p < 0.001$; $\beta$reward = -6.52, $t = -4.00$, $p < 0.001$), suggesting it functions as a top-down policy command for strategic exploration. These findings provide direct electrophysiological evidence for a dynamic circuit where dissociable value representations are integrated through mode-switching connectivity patterns, enabling flexible control of human decision-making.

**Keywords:** *Exploration-Exploitation, Decision-Making, Intracranial EEG, Neural Connectivity*

## Young Children Use Causal Knowledge to Guide Question Asking

*Elizabeth Lapidow*[1], Amberley R. Stein[2], Giovanni Thomas[2], & Caren M. Walker[2]

[1] Department of Psychology, University of Waterloo [2] Department of Psychology, University of California San Diego

**Abstract:** Question asking is an essential tool for learning. However, it requires successfully *identifying* what's informative to ask about and *generating* effective queries to do so. Preschoolers are already adept question-askers (Chouinard et al., 2007), but adult-like questioning does not develop until early school years (Ruggeri et al., 2016). Similarly, 5-year-olds readily identify which questions are most effective in terms of number of hypotheses targeted (Ruggeri et al., 2017), but whether they can identify conceptually relevant questions is uncertain (Davidson, 1991; Jirout & Klahr, 2020). Here, we investigate whether 5- and 7-year-olds use their abstract understanding of real-world *causal relationships* to identify (Exp1) and generate (Exp2) questions. Children heard a description of an event with an unknown cause (e.g., "*What animal made the mess?"*), which included highlighted 'clues' implying traits of the true cause (e.g., "*The mess was on top of the fridge."*). In Experiment 1, they chose between questions, both conceptually similar, but only one causally relevant (e.g., *"Can it make noise?"* versus *"Can it climb?"*). Children (N=96) overwhelmingly selected causally relevant questions (78.92%, $p < 0.001$, 95% CI [67.39, 77.96], two-tailed binomial), showing the preference in all trials and both age groups. In Experiment 2, the story was followed by an open-ended prompt to generate questions from scratch. Our results reveal success in even the youngest children, as well as evidence of developmental change consistent with the existing question-asking literature (Ruggeri & Lombrozo, 2015). Both age groups spontaneously employed causal knowledge to target relevant information (66% 5-year olds' questions; 84% 7-year-olds' questions), but

differed in question-asking effectiveness. The majority of 7-year-olds' questions sought to narrow the space of possible causes, while 5-year olds more often inquired about individual possibilities. This work offers insights into self-directed learning, development of question-asking, and ultimately, how learners arrive at good hypotheses given nearly infinite possibilities.
Keywords: *question-asking ; causal reasoning ; cognitive development ; decision making ; hypothesis generation*

## Curiosity in the moral domain: When and why people seek moral information

*Jordan Wylie*[1], Jane Acierno[2], Max Kleiman-Weiner[3], Sara Constantino[4], & Liane Young[5]

1: Cornell University 2: Northeastern University 3: University of Washington 4: Stanford University 5: Boston College

Abstract: Curiosity motivates information-seeking and knowledge acquisition across the lifespan, yet its role in the moral domain—a domain central to adaptive social behavior—remains underexplored. To address this gap, we developed a novel moral information seeking task and examine when people seek information about real-world, morally ambiguous scenarios. Specifically, we test whether 1) there is a relationship between curiosity and information-seeking in the moral domain, and whether 2) judgments of moral valence (i.e., morally good versus morally bad) influence the relationship between curiosity and information-seeking. Across two experiments (N = 1,069), participants learned about an ambiguous real-world moral agent and then had the opportunity to sample others' real moral judgments about that agent. In pilot work and replicated in Experiment 1, greater self-reported curiosity about a moral agent but lower confidence in one's own moral judgment predicted increased levels of information-seeking ($p$'s < .001). People who reported being curious or unsure about a moral agent sampled more information about them. Critically, moral valence too shaped information-seeking behavior: Scenarios perceived as morally good elicited *less* information-seeking ($p$ < .001) than those seen as morally bad. Experiment 2 replicated these effects and introduced a measure of how justified the moral actions of the agent seemed to explore one possible driver of increased information sampling for morally bad compared to good judgments. Although justification did not directly predict sampling ($p$ = .17), it indeed moderated the link between perceived immorality and information seeking ($p$ < .001): Participants who viewed an action as immoral and unjustified sought more information than those who say an action as good or as justified. Together, these findings suggest that curiosity prompts information-seeking in the moral domain, but this relationship is shaped by people's priors and moral evaluations. The role of information-seeking in moral belief updating will be discussed.
Keywords: *Morality; Curiosity; Uncertainty; Information-seeking*

## Representations of the intrinsic value of information in mouse orbitofrontal cortex

*Jennifer Bussell*
Colombia University

**Abstract:** Animals are motivated to acquire knowledge. They often seek information that reduces uncertainty, even if it does not lead to increased external reward and comes at a cost. This implies that information is intrinsically valuable. However, due to its cognitive nature, the neural mechanisms that assign value to information-associated stimuli to guide knowledge seeking are poorly understood. We have therefore developed an information seeking task for mice and used it to investigate neural population representations of information-associated odor stimuli. In this task, mice choose to receive probabilistic water reward in either of two nosepoke ports, which differ only in whether they provide information via odor that reveals the reward amount but cannot be used to increase reward. Mice are cued at trial start by odor in a third port which reward ports are available, such that they learn an association between odor and predicted information. Mice strongly prefer the information port (68% mean preference, $p<0.001$, N=33). Moreover, mice exchange water to pay for information, preferring the information port even when it decreases their water reward. We fit reinforcement learning parameters to choices between information and water to model the subjective value of information (mean 38% water value exchanged for information, N=4). Thus, like humans and other animals, mice display an economically sub-optimal information bias in their decision making, behaving as if information has intrinsic value. To ask how representations of neutral odor stimuli are transformed by association with information value, we imaged neurons in orbitofrontal cortex (OFC) using miniature microscopes in mice learning the information seeking task (N=7 mice, 1138 cells). Decoding analysis and dimensionality reduction revealed a population representation of predicted information comprising 18% of OFC neurons. The difference between neural activity in anticipation of information vs. no information scaled with the time animals spent in a state of uncertainty, consistent with the information prediction representation being a scalar value signal. We observed distinct populations of neurons responsive to odors predictive of information and odors predictive of water reward (18% of OFC cells each, 30% of which overlap). Moreover, a latent variable model recapitulated distinct representations of intrinsic information versus extrinsic water value in the low-dimensional dynamics of OFC activity. These data suggest that mice have evolved distinct pathways in OFC that represent the intrinsic value of knowledge and the extrinsic value of water reward.

**Key words:** *D - Risk & Uncertainty; H - Learning & Memory; I - Valuation & Decision Making*

# Day 1 – Tuesday, September 30, 12:00 - 12:15

### (16). Chimpanzees adapt their exploration to key properties of the environment

*Lou Marie Haux*
Max Planck Institute for Human Development

**Abstract:** The core function of cognition is to enable organisms to deal effectively with environmental complexity and the uncertainty it brings. One way of coping with an uncertain world is exploration: gathering information and thereby reducing uncertainty. The investigation of exploratory strategies preceding choices with tangible consequences offers a window onto organisms' ability to reckon with uncertainty. Explorative behavior has been found to depend on properties of both the environment and the organism. Humans engage in more exploration in unpredictable and complex environments and adapt their exploration strategies to the environment. Specific dispositions that vary across individuals, such as openness to experience and risk preference, have also been associated with explorative behavior. We harness and adapt the human decisions-from-experience paradigm to investigate exploration under uncertainty in chimpanzees. In our study, chimpanzees ($N$ = 15; eight females) are simultaneously confronted with an uncertain option (with outcome variance) and a safe option (without outcome variance) and tested in both stable and changing environments. Results reveal that, as in human exploration, how and how much chimpanzees explore depends on the environment. One key environmental property is change: Chimpanzees explore more across trials in changing than in stable conditions. Consistent with the assumption of classic economic models that variance indicates risk, chimpanzees also explore more when they experience variance in the options' outcomes. Individual risk and uncertainty preferences did not have a statistically significant effect on exploratory efforts. These findings suggest that chimpanzees and humans share key similarities in the way they respond to risk and uncertainty.

**Key words:** *Exploration, Uncertainty, Risk, Environment, Chimpanzees*

### (20). Learning how to learn: Evidence for an explore-exploit tradeoff in information search

*Madeline Klotz* & Emily G. Liquin
University of New Hampshire

**Abstract:** In a world where opportunities for learning are everywhere, people constantly face decisions about what information to pursue and how to pursue it. Sometimes, it is clear how to explore most effectively (e.g., consulting a baking blog to answer a question about making cookies). However, we often have uncertainty about which action will produce the most information. The current research investigates how people explore when they are uncertain about the informativeness of different actions. We propose that these decisions are governed by an explore-exploit tradeoff. At each moment, one can either exploit an action known to produce high-quality information or explore an unknown action to learn its potential informativeness. By exploring unknown actions, people can learn how to explore effectively in the future. Critically, we propose that these explore-exploit decisions operate independently of external reward: the intrinsic motivation to gain

information should drive people to explore the space of possible exploratory actions. To test this prediction, we adapted a task from Wilson et al. (2014). In our task, participants make sequential choices between two actions, each of which reveals information: words in an ongoing story (Experiment 1, N=171) or pixels in a hidden image (Experiment 2, N=173). One action reveals more information on average, but participants are initially uncertain about each action's informativeness. By exploring each action, participants can learn how to explore effectively. In both experiments, we found evidence for random exploration (decision noise; *p*s < .001) directed exploration (preferring the more uncertain action; *p*s < .001), and exploitation (preferring the more informationally promising action; *p*s < .01). However, people explored uncertain actions even without the possibility of future exploitation (differing from typical manifestations of the explore-exploit tradeoff; Wilson et al., 2014). Thus, though there is evidence for an explore-exploit tradeoff, exploration is largely insensitive to future utility.

Keywords: *Explore-exploit tradeoff, exploration, learning, intrinsic motivation*

## (13). How Decision-Process Information Shapes Inferences in Cooperative Interactions

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Abstract: Information seeking is central to human learning and adaptation, yet how people explore others' hidden preferences in social settings remains poorly understood. In this study, we examined whether people strategically choose actions to reduce uncertainty about others and whether real-time attentional cues enhance this process. We developed an interactive bargaining paradigm involving 79 pairs of participants (mean age = 24.9 ± 6.9 years; 113 female), assigned to buyer and seller roles. Sellers aimed to learn buyers' preferences by offering products defined by three attributes (e.g., speed, comfort, safety) across 20 categories. In each trial, sellers could make up to four sequential offers. Buyers accepted or rejected each offer and earned more for accepting high-utility products, while sellers received fixed points for each successful sale. Critically, only sellers in the attention condition had access to buyers' real-time eye movements.

Buyers' behavior revealed stable preference signals: acceptance rates increased with utility, RTs were longer for ambiguous decisions, and first fixations aligned with the most-weighted attribute in 55% of trials. Sellers adapted based on buyer RTs ($B = 2.47$, $p < .001$) and in the gaze condition, adjusted offers based on first fixations ($p = 0.016$). Using a Bayesian learning model, we quantified how sellers integrated feedback over time. The model included parameters for information gain and prior stickiness, revealing that sellers made offers not only to maximize reward but also to reduce uncertainty ($\lambda = 0.18 \pm 0.04$, $\eta = 0.68 \pm 0.04$). These findings suggest that humans engage in structured, model-based exploration in social contexts, using both behavioral and attentional signals to guide learning. Even when real-time gaze was noisy or costly to interpret, people leveraged it to shape offer selection. This highlights a fundamental mechanism of social curiosity: learning about others through interactive, information-seeking behavior.

# Day 2 – Wednesday, October 1, 11:45 - 12:15

### (41). Large Language Models Think Too Fast To Explore Effectively

Lan Pan*, *Hanbo Xie*†*, Robert C Wilson
School of Psychology, Georgia Institute of Technology

**Abstract:** Large Language Models (LLMs) have emerged with many intellectual capacities. While numerous benchmarks assess their intelligence, limited attention has been given to their ability to explore—an essential capacity for discovering new information and adapting to novel environments in both natural and artificial systems. The extent to which LLMs can effectively explore, particularly in open-ended tasks, remains unclear. This study investigates whether LLMs can surpass humans in exploration during an open-ended task, using Little Alchemy 2 as a paradigm, where agents combine elements to discover new ones. Results show most LLMs underperform compared to humans, except for the o1 model, with those traditional LLMs relying primarily on uncertainty-driven strategies, unlike humans who balance uncertainty and empowerment. Results indicate that traditional reasoning-focused LLMs, such as GPT-4o, exhibit a significantly faster and less detailed reasoning process, limiting their exploratory performance. In contrast, the DeepSeek reasoning model demonstrates prolonged, iterative thought processes marked by repetitive analysis of combinations and past trials, reflecting a more thorough and human-like exploration strategy. Representational analysis of the models with Sparse Autoencoders (SAE) revealed that uncertainty and choices are represented at earlier transformer blocks, while empowerment values are processed later, causing LLMs to think too fast and make premature decisions, hindering effective exploration. These findings shed light on the limitations of LLM exploration and suggest directions for improving their adaptability.

**Keywords:** *Large Language Models, Exploration, Empowerment, Uncertainty, Reasoning*

### (11). Compulsivity changes information-search and evidence-accumulation strategies in the presence of task-relevant and task-irrelevant uncertainty

Veronica R. Smith; Isabella M. Acerra; Olivia R. Barbarini; *Andra Geana*
Providence College

**Abstract:** *Background.* While compulsivity is believed to alter the uncertainty computations involved in learning, depending on task setup, compulsive individuals may show deficits (including maladaptive oversampling or reduced memory and/or confidence in what was sampled), or relatively intact learning. Recently, we showed evidence of impaired integration across uncertainty levels in OCD; here, we explore whether compulsivity biases individuals toward identifying more sources of uncertainty than necessary for their task, and whether uncertainty integration deficits under those circumstances may explain compulsive learners' performance.
*Methods.* Three experiments (N1=121, N2 = 89, N3=29) used a novel categorization task with different levels and types of uncertainty. Participants categorized artificially-generated hybrid animals that varied in perceptual uncertainty (very low, e.g. "90% zebra/10%

donkey" to very high, e.g. "50% goat/50% sheep") and conceptual uncertainty (low, e.g. goat/sheep, to high, e.g. goat/dolphin). Notably, only perceptual uncertainty was directly related to categorization difficulty, and the task could be solved fully by resolving that type of uncertainty; conceptual uncertainty was an extraneous variable, not mentioned in task instructions. Participants categorized 70 hybrids into one of two parent categories and completed compulsivity, anxiety, and impulsivity questionnaires. Experiments 1 and 2 ran online, while Experiment 3 was lab-based and included eye-tracking.
*Results*. Across experiments, higher compulsivity linked with higher reaction times and reduced sensitivity of decision times to uncertainty. Gaze and pupil analysis in Experiment 3 showed lower saccade velocities (generally associated with lower confidence) in low uncertainty conditions, and more gazing to parent categories ("conceptual checking") overall in higher-compulsivity individuals. These individuals also showed lower pupil diameters, longer gaze times, and reduced accuracy for decisions on conceptually uncertain stimuli. Drift diffusion model (DDM) fits showed higher decision thresholds under uncertainty and failures to dynamically adjust drift rate between low and high uncertainty conditions in high-compulsivity participants. Interestingly, linking drift rate to conceptual uncertainty improved fits only for highest-compulsivity participants.
*Implications*. Our results are consistent with previous literature suggesting higher decision thresholds and slower evidence accumulation in compulsive individuals. Additionally, higher-compulsivity participants' sensitivity to conceptual uncertainty suggest that they may overweigh irrelevant information or attempt to integrate extraneous sources of uncertainty; we propose this as a potential mechanism linked to the lower confidence and deficits in evidence accumulation often linked to compulsivity.
Keywords: *compulsivity; uncertainty computations; modelling;*

## Curious Connections: Individual Differences in Curiosity, Attentional Control, and Sociopolitical Attitudes

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Abstract: Curiosity is widely recognised as a driver of learning and exploration, yet its relationships with fundamental cognitive and social constructs remain unclear. This pre-registered study investigated individual differences in curiosity and their associations with attentional control and sociopolitical attitudes. Data were collected online via Prolific from 447 participants (aged 18–65). Curiosity was assessed using the 5DCR scale, measuring Joyous Exploration (JE), Deprivation Sensitivity (DS), Stress Tolerance (ST), Thrill-Seeking (TS), Overt Social Curiosity (OSC), and Covert Social Curiosity (CSC; Kashdan et al., 2020). Attentional control was measured using validated versions of the Flanker, Stroop, and Simon tasks (Burgoyne et al., 2023). Participants also completed the HEXACO personality inventory, the Attentional Function Index (AFI), and scales assessing political extremism, conspiracy beliefs, right-wing authoritarianism (RWA), and dogmatism. Analyses in R included bivariate correlations, linear regressions, and mediation/moderation models. Latent profile analysis (LPA) is also being conducted to identify distinct curiosity profiles and their associations with attentional and ideological variables. Preliminary findings show significant negative correlations between attentional control and several curiosity

dimensions (DS: $r = -.17$; TS: $r = -.16$; OSC: $r = -.16$; all adjusted $p$-values < .01). In contrast, attention functioning (AFI) showed positive associations with curiosity (JE: $r$ = .50; DS: $r$ = .25; ST: $r$ = .40; OSC: $r$ = .23; all adjusted $p$-values < .001). Significant positive associations were also observed between curiosity (particularly DS and TS) and political extremism, conspiracy thinking, and RWA. LPA supports a four-profile solution, with emerging group differences in attentional control and ideological beliefs. These findings contribute to a growing literature on curiosity as a multidimensional construct, suggesting that different facets of curiosity may be differentially associated with cognitive and ideological outcomes.

**Pre-registrations:**

- Curiosity and attentional control: https://osf.io/cuygz/
- Curiosity and attitudes/values: https://osf.io/9wg8k/

**Keywords:** *Curiosity, Attentional Control, Individual Differences, Political Extremism, Conspiracy Beliefs*

## (4). Perseveration as exploration: repetitive selection facilitates delayed credit assignment

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**Abstract:** Assigning credit to actions with delayed consequences is a core challenge for adaptive behavior, yet little is known about whether and how individuals learn from temporally extended outcomes. Here, we introduce a novel behavioral paradigm to dissociate immediate and delayed action outcome relationships, enabling precise investigation of temporal credit assignment across three studies (N = 901). While individuals varied widely in how effectively they assigned credit to actions with immediate versus delayed consequences, we show that those who further repeated actions demonstrated enhanced delayed credit assignment. Furthermore, computational modeling revealed that those participants who repeated actions more frequently were more likely to adopt model-based learning strategies and ultimately made more effective decisions when pursuing long-term goals. Importantly, this benefit was not driven by agency: even participants passively experiencing yoked action sequences showed improved long-term learning. While repetition is often cast in a negative light as perseveration, these results highlight a key role for this policy during learning. Specifically, repetitive action selection can serve as a structured exploration strategy that bridges temporal gaps in causal inference, highlighting the powerful role of action sequencing in how we learn from experience more generally.

**Keywords:** *credit assignment, perseveration, long-term learning, action selection*

## (8). Fixation-Evoked Potentials Reveal Bayesian Belief Updating Processes in Multi-Attribute Choice

*Jordan Deakin*

University of Hamburg

**Abstract:** *Introduction.* Whether it be buying a new phone or finding the right hotel, many decisions problems require integrating information from multiple attributes in order to identify the best option. Our recently proposed theory of Multi-Attribute Search & Choice (MASC, Gluth et al., 2024) assumes this process follows a hierarchical Bayesian belief updating scheme. Specifically, posterior beliefs about the value of attributes, and in turn the options themselves, are iteratively updated through samples obtained from fixations. When one option is deemed sufficiently superior to all alternatives, a choice is made.
*Methods.* In this combined EEG and eye-tracking study, we explored whether the process of belief updating proposed by MASC is predictive of the EEG signal in terms of fixation-evoked potentials (FEPs). Participants (N = 50) completed a multi-attribute choice task in which they chose between two smartphones on the basis of star ratings for three attributes (battery capacity, screen size and storage space). We fitted MASC to the eye-tracking data using choice, number of fixations, choice and the distribution of attention across items to guide parameter estimation. By simulating the model with the best fitting parameters, we derived predictions of the strength of belief updating at each fixation. Using linear deconvolution modeling, we were able to assess the effect of these model-derived estimates, while also controlling for overlapping activity evoked by successive fixations and confounds such as saccade amplitude and fixation number.
*Results.* Our findings demonstrate that MASC not only captures key patterns in the behavioral data, such as the distribution of attention to attributes based on their importance, but also provides meaningful predictions at the neural level. Specifically, regression analyses using threshold-free cluster enhancement to correct for multiple comparisons revealed that the predicted strength of belief updates positively modulated activity in posterior electrodes. This result was driven by two separable dynamics, a P3-like FEP from 250-400ms post fixation onset as well as a late positivity-like modulation between 400-800ms, both at the level of individual attributes and options.
*Conclusion.* Our results provide converging behavioral and neural evidence that multi-attribute decision making involves dynamic, fixation-driven updating consistent with Bayesian inference as formalized by MASC. Consistent with previous work establishing the P3 as a belief updating signal, we show that model-predicted belief updates are reflected in FEPs with comparable timing and topology.

# Knowledge of information cascades through social networks facilitates strategic gossip

*Alice Xia*[1], Yi Yang Teoh[1], Matthew R. Nassar[1,2], Apoorva Bhandari[1,3] & Oriel FeldmanHall[1,2,3]

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**Abstract:** Social networks are composed of many ties among many individuals. These ties enable the spread of information through a network, including gossip, which comprises a sizeable share of daily conversation. Given the number of possible connections between people in even the smallest networks, a formidable challenge is how to strategically gossip—to disseminate information as widely as possible without the target of the gossip finding out. Here we find that people achieve this goal by leveraging knowledge about topological properties, specifically, social distance and popularity, using a gossip-sharing task in artificial social networks (experiments 1–3, N = 568). We find a similar pattern of behavior in a real-world social network (experiment 4, N = 187), revealing the power of these topological properties in predicting information flow, even in much noisier, complex environments. Crucially, participants showed sensitivity to structural features even when memory for specific ties was poor, suggesting that gossip decisions may be guided by abstract network representations. Further, people selectively integrated individual-level attributes (i.e., the trustworthiness of each person in the network) to fine-tune their strategy. Computational modelling revealed that these adaptive behaviors are best captured by a cascade-based representation of network structure, consistent with the Katz model, which flexibly encodes how information may diffuse across multiple paths.

# Posters

## Session 1: Tuesday, September 30, 1:15 - 2:45

### (2). A Reinforcement Learning Model of Voluntary Exposure to Specific Curiosity

*Nadia Ady*

**Abstract:** Specific curiosity, "the desire for a particular piece of information,"(Loewenstein, 1994, p. 77) has been characterized by our willingness to expose ourselves to it voluntarily (ibid., pp. 84-85). Humans willingly turn on Netflix and begin crossword puzzles and mystery novels, despite knowing that these situations are highly likely to drive them into curiosity-motivated behaviour.

This work presents a reinforcement learning method that shows how voluntary exposure to curiosity-inducing situations could arise from a mechanism motivating an agent to satisfy its curiosity as directly as possible. The experiments are performed in a fully-observable grid world to support understanding. Once curiosity is induced (which, in this demonstration, only happens in one state), the agent uses its model to learn a value function guiding it to a curiosity satisfying target. While it traverses to its target, it updates its persistent value function, with the learning mechanism for voluntary exposure bootstrapping over the sum of the persistent and temporary values.

Observing the agent's value function over the state space over time, the agent learns to persistently value the curiosity inducing situation, without accumulating value in the tar gets of curiosity, agreeing with the observation that, in hu mans, "information that completely resolves uncertainty no longer motivates exploratory behavior" (Gruber and Ranganath, 2019, p. 1014). Further, ablating the learning mechanism for voluntary exposure results in many fewer visits to targets of curiosity, demonstrating the value of voluntary exposure for curiosity-driven learning.

While the literature has suggested that obtaining information is rewarding (e.g., Bromberg-Martin and Monosov, 2020), less attention has been given to what mechanisms would encourage us to return to situations in which we are likely to become curious. Future work will compare other methods of accumulating value in curiosity-inducing situations (e.g., directly rewarding becoming curious) and explore which methods are most consistent with human data.

**Keywords:** *curiosity, reinforcement learning, voluntary exposure*

**References**

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Gruber, M. J., and Ranganath, C. 2019. How curiosity en hances hippocampus-dependent memory: The prediction, appraisal, curiosity, and exploration (PACE) framework. Trends in Cognitive Sciences 23(12):1014 – 1025.

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## (6). Curiosity and Aging: Implications for reducing digital exclusion among older adults

*Shiyun Chen*

**Abstract:** Empirical evidence suggests that trait level curiosity decreases as people age. However other studies indicate older adults have an equivalent or even greater capacity for state level curiosity. Novel technologies offer promise to enhance older adults' lives, but older adults are slower to adopt these technologies. In three experiments, we test whether inducing state curiosity increases usage of digital tools among older adults and reduces digital exclusion. In Study 1, we employed a 2 (age group: younger vs. older adults) × 2 (curiosity condition) between-subjects design to test our hypotheses. The results revealed that older adults, in general, exhibited greater curiosity about new technologies ($t = 3.30$, $p < .01$), were more likely to express willingness to adopt the new technology after the experiment ($t = 2.91$, $p < .01$), and showed greater curiosity toward other new technologies ($t = 3.95$, $p < .01$), even though they found the learning process more difficult ($t = 5.30$, $p < .01$). However, there was no significant difference in curiosity between the curiosity conditions ($t = 0.24$, $p = .40$), suggesting that all participants were generally curious regardless of condition. In Studies 2 and 3, we used similar experimental designs but tested different technologies: the Oura Ring 4 (Study 2) and Switti (Study 3). In both studies, participants across all conditions consistently reported high curiosity levels. This suggests a potential selection bias, likely because participants were recruited through an online platform and may naturally be more interested in technology, and who are not interested in the study can quit whenever they want during the experiment. Overall, our findings suggest that, contrary to some prior research, older adults can be highly curious and open to exploring new technologies.

**Key words:** *Curiosity, Aging, Technology adoption*

## (10). How We Learn What to Believe and Who to Trust: Understanding Joint Updating using Bayesian Inference

*Prashanti Ganesh 1*, David Levan 1, Noham Wolpe 2, Matthew Nassar 1

1 Brown University 2 Tel Aviv University

**Abstract:** In everyday life, people constantly revise beliefs—about policies, events, or other topics—based on new information, often from news sources. This process requires not only updating beliefs about the topic ("Is this policy good?") but also judging the credibility of the source ("Can I trust this outlet?"). While past research has examined belief-updating in simplified tasks, it's unclear whether similar mechanisms operate in real-world contexts, where beliefs are strong and shaped by broader belief systems. We investigated the cognitive and computational mechanisms supporting real-world belief updating by developing a Bayesian model that jointly updates beliefs about both the topic and the information source. Simulations yielded two predictions: (H1) people will rate sources as more credible when the information aligns with their prior beliefs, and (H2) higher perceived credibility will amplify belief updating. We tested these predictions in a novel "news-based inference" task, where 180 participants updated

beliefs about real-world topics and source credibility. We manipulated source credibility (high: 10% misinformation vs. low: 50%) and alignment (information aligning with participants' views 75%, 50%, or 25%) in a between-subjects design. Supporting H1, in high credibility conditions, sources were rated as more credible when their information aligned with participants' prior beliefs—demonstrating confirmation bias. In low credibility conditions, we found a U-shaped pattern: sources moderately aligned (50%) were rated most credible, suggesting that balanced agreement may signal trustworthiness when credibility is suspect. Supporting H2, higher perceived credibility led to greater belief updating across both conditions. These findings suggest that people integrate both content and source trustworthiness when updating beliefs. They rely more on confirmation bias when a source appears credible but show adaptive skepticism when source reliability is in question—revealing a nuanced mechanism for navigating complex, real-world information environments.
**Keywords:** *Information Seeking, Belief Updating, Bayesian Inference, Confirmation Bias*

## (12). How AI Supports Creative Information Seeking: The Case of Creative Problem Solving

*Christian Gilde*
University of Montana

**Abstract:** While recent studies have demonstrated the powerful performance of Artificial Intelligence (AI) on generating quality outputs, there is insufficient research on how good AI can support information seeking in the context of creative problem-solving. Creative problem-solving approaches present a rich new territory to investigate AI's capacity to help produce real-world outcomes. Five years of data produced by an international competition, dating back to 2019, and generated by advanced high school students were studied. This presentation examines the information seeking performance of AI and humans during an international future problem-solving competition. In addition, the solutions were blind-scored by randomly assigned human evaluators utilizing a detailed measurement rubric--multiple rounds of evaluations took place. Once scored, the human and the AI information seeking outcomes were compared. Exploratory results of this research suggested that the AI information seeking outcomes were of similar quality than those produced by humans. Interestingly, a segment-wise breakdown of the AI results showed distinct patterns at different student levels. In summary, AI can be a useful information seeking tool that can alleviate many biases and differences in human information seeking and, thus, foster a greater drive for exploration.
**Keywords:** *Artificial intelligence; information seeking; creativity; creative problem solving*

## (14). Quantum Curiosity

*Goren Gordon*

Luddy School of Informatics, Computing, and Engineering, Indiana University Bloomington, Indiana, USA

**Abstract:** *Background:* Artificial curiosity algorithms have gained much attention in the last decade. One explored implementation has been the *Curious Data Scientist framework*, in which the curiosity loop, including a machine learning (ML) module that supplies intrinsic rewards to a reinforcement learning (RL) agent, has been used for the data science pipeline, such as curious feature selection, instance selection, and clustering. With the rise of quantum computers, a clear path to *Quantum Curiosity* appears, in which Quantum Machine Learning (QML) replaces the (classical) machine learning module, and Quantum Reinforcement Learning (QRL) replaces the (classical) agent.
*Methods:* We have implemented a Quantum Curious Feature Selection (QCFS) algorithm, with QML to learn classical classification problems and a QRL that learns feature selection. For both QML and QRL, we implemented a quantum neural network based on a variational
quantum circuit architecture, where classical input features are embedded into quantum states through angle encoding. In an exploratory study, we used benchmark datasets to compare QCFS to its classical analogue.
*Results:* We ran 1000 episodes of the curiosity loop, with 10 runs for each Learner-Agent combination. We show that QCFS achieves the best and most stable result. Iris dataset, 3 out of 4 features, accuracy Mean±STD (Best): ML+RL: 0.58±0.21 (0.87), ML+QRL: 0.51±0.17 (0.70), QML+RL: 0.70±0.20 (0.88), QML+QRL: 0.72±0.23 (0.96). Breast Cancer dataset, 3 out of 30 features, accuracy Mean±STD (Best): ML+RL: 0.78±0.12 (0.90), ML+QRL: 0.63±0.12 (0.88), QML+RL: 0.70±0.18 (0.90), QML+QRL: 0.74±0.15 (0.91).
*Conclusion:* The combination of quantum computers with artificial curiosity gives rise to a fascinating synergy of speed and expressiveness of both frameworks. Leveraging quantum computers' ability to expedite search for the benefit of curiosity-based exploration can prove to be crucial for open-ended learning. Complementarily, using curiosity-based exploration to find optimal configurations for (the currently limited) quantum computer architectures can prove to be highly beneficial.

**Keywords:** *Quantum computers, curiosity loop, feature selection.*

## (18). Statistical Learning Shapes Cognitive Maps of Signed Social Networks

*Yi-Fei Hu1*, Marc-Lluis Vives2, Apoorva Bhandari1, Oriel FeldmanHall1,3

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**Abstract:** Building cognitive maps of signed social networks—those containing both friendly and antagonistic ties— is essential for navigating social life. While dominant accounts attribute systematic biases in these maps to schemas like Balance Theory, we propose that
such biases emerge from statistical learning of real-world relational patterns. Across four studies—combining behavioral experiments, computational modeling, and analyses of ten longitudinal signed networks (over 150,000 nodes and 1.6 million ties)—we find that

people's inductive biases simply reflect statistical structures of their social environments. These biases align more closely with naturally occurring motifs than the rules of Balance Theory. When exposed to artificial networks that violate real-world statistics, individuals gradually, yet flexibly adapt their inferences, implicating statistical learning as the underlying mechanism. These findings position statistical learning as a foundational process shaping how humans encode and reason about complex signed social networks, providing a new lens for understanding socio-cognitive map building.
Keywords: *Cognitive Map; Social Network; Statistical Learning; Balance Theory*

## (22). Competitors or Opportunities? Mutual Exclusivity Alters Neural and Attentional Processing of Choice Alternatives

*Xiamin Leng*
University of California, Berkeley

Abstract*: Introduction.* Decisions form a central bottleneck to most tasks, one that people often experience as costly. We recently showed that this cost is intensified when decision-makers feel as though choosing one option sacrifices others (mutually exclusive), and that this cost can be reduced by framing choices as inclusive (e.g., allowing selection as many as they want, as in buffets). A prediction arising from these findings is that exclusivity may modulate how people perceive the next-best options in a set, such that options that are evaluated as competitors during exclusive choice may be evaluated as potential opportunities for future selection during inclusive choice. To test this prediction, we examined patterns of fixation and neural activity while participants made choices that were either mutually exclusive or inclusive.
*Methods.* We recorded fMRI and eye-tracking data from participants (N=30) performing a value-based decision making task in which they chose their favorite option from sets of four consumer products. Prior to each choice, participants were informed whether they would later have the opportunity to choose more items from the set (inclusive choice) or not (exclusive choice). We focused our neural and eye tracking analyses only on the first choice of each set.
*Results.* When participants made exclusive choices, we found that they fixated each item in proportion to its rank and value - fixating the best option most and the worst item least. By contrast, for inclusive choices, they fixated the top two items to a similarly high degree and the bottom two to a similarly low degree - this pattern mirrored our finding that participants later added on average one additional item to their set. Consistent with this boundary between two and three items forming a distinct threshold for their evaluations, when we examined neural activity during inclusive choice in a region of dorsal ACC previously associated with choice anxiety, we found that this activity increased the worse the second-ranked option was and the better the third-ranked option was. This dissociation was absent during exclusive choice.
*Discussion.* Our work provides the first insight into the influence of mutual exclusivity on the neural and attentional dynamics during decision making. Our findings suggest that exclusivity modulates how people process the next-best items in a set: When only one option can be chosen (exclusive choice), each of the lesser options gets diminishing priority in proportion to its rank. When multiple options can be chosen, participants instead

prioritize those items that they plan to select and deprioritize those they plan to discard.
**Keywords:** I - Valuation & Decision Making; K - Attention

### (24). Inferring Learning Progress in Goal-Directed and Open-Ended Tasks

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[2]University of California, Berkeley

**Abstract:** Curriculum learning involves constructing and navigating increasingly difficult tasks to achieve long-term goals. Previous research has shown that 5- to 7-year-old children adapt their learning trajectory based on their performance. Similarly, reinforcement learning agents, when trained with level competence as an auxiliary reward, significantly improved in performance. Overall, these findings demonstrate that intrinsic reward signals based on competence can play a crucial role in curriculum learning. Yet, little is known about how observers—human or artificial—infer learning progress from another agent's behavior, especially when goals are implicit or absent. While previous work has explored how one may design a curriculum, less is known about how individuals infer curricula and the influence of goals. We developed a novel experimental paradigm in which adults, children (ages 5–7), and GPT-4o were shown level transitions in a procedurally generated game and asked to infer a player's progress under two conditions: goal-directed (explicit target and reward) and open-ended (no target or reward). We found, through regression analyses, that goal framing significantly biased human participant judgments: in the goal-directed condition, observers over-attributed competence when transitions approached or surpassed the target. In contrast, in open-ended conditions, participants relied on incremental, effort-based heuristics. However, using the same study for testing AI models, we found that the presence of a goal did not have a significant effect on inferring progress. These findings suggest that while GPT-4o can approximate human judgments in structured learning tasks, it lacks the deeper intentional modeling that guides human generalization. Therefore, this work not only elucidates how people represent and evaluate learning trajectories in both goal-oriented and exploratory contexts but also offers insights into the limitations of current AI systems in modeling human-like inference.
**Keywords:** *curiosity-driven inference, curriculum learning, human-AI comparison, goal-directed behavior, learning progress*

### (26). The dynamics of explore-exploit decisions suggest a threshold mechanism for reduced random exploration in older adults

*Caroline Phelps*
*Georgia Institute of Technology*

**Abstract:** When faced with a choice between exploring an unfamiliar option or exploiting a familiar one, older adults explore less and exploit more than younger adults. Recent work has suggested that one cause of decreased exploration in older adults is a reduction in their use of "random exploration" – exploration driven by behavioral variability. How and why this reduction in random exploration occurs is unknown. Thus, we investigated the mechanism of this age related difference in random exploration through the lens of a drift

diffusion model (DDM) of the explore-exploit choice. We used the Horizon task, in which healthy younger or older adults chose between two slot machines that have either equal or unequal starting information and pay out varying probabilistic rewards. On each trial the slot machines have a short or long 'horizon', i.e. 1 or 6 free choices. Choice and response time data was modelled using the drift diffusion model (DDM) based on (Feng *et al.* 2020). In this model, random exploration can be modulated by two mechanisms – the fidelity with which information about the choice is represented in the brain, the "signal-to-noise ratio" (SNR), and the amount of information required to make a decision, the "decision threshold." We found that older adults had a lower SNR and a higher threshold than younger adults. In younger adults the SNR for reward and decision threshold both decrease when it is more profitable to explore. However, in older adults, the SNR for reward decreased to a lesser extent and the did threshold did not significantly decrease. Overall, these results suggest that reduced random exploration in aging is driven by higher response thresholds in older adults, which may compensate for the reduced signal-to-noise ratio with which decision information is represented in the aging brain.

Keywords: *Aging, Decision Making, Drift Diffusion Model*

## (28). How do people maintain false beliefs? Modeling anchoring biases during learning and inference

*Magda del Rio*[1], Noham Wolpe[2,3], Matthew R. Nassar[1]

Brown University, Providence, RI, USA [2] Tel Aviv University, Tel Aviv, Israel [3] University of Cambridge, Cambridge, UK

Abstract: People sometimes maintain false beliefs despite contradictory evidence, explaining it away by integrating it into complex frameworks that protect their core assumptions. We refer to this process as explanatory anchoring bias. Unlike confirmation bias or standard belief-updating models, this mechanism involves modifying auxiliary beliefs, rather than selectively regulating attention to evidence supporting the false belief. An explanatory anchoring bias better reflects real-life naturalistic conditions, where multiple, interrelated information sources shape belief formation, and may better account for clinical observations, such as the persistence of false beliefs in delusions. Here, we developed a new task and computational model to capture this bias. Agents learn the value of three stimuli concurrently in a four-phase task. Phase 1 introduces a potentially false assumption through a single unambiguous piece of evidence about one stimulus, by drawing from a distributional extreme. Phase 2 involves inference about individual stimulus values by providing ambiguous summed stimulus information (total value of all stimuli), which can drive the formation of internally consistent beliefs. Phase 3 presents disambiguating evidence about individual stimuli which could correct the false initial assumptions if integrated with previous knowledge. Phase 4 returns to the ambiguous sum trials to assess the persistence of initial assumptions. Computational modeling revealed qualitatively distinct behaviors between Bayesian and reinforcement learning (RL)-inspired agents. Critically, Bayesian agents quickly corrected biased estimates after receiving disambiguating evidence, while RL agents showed delayed correction and higher error, consistent with higher explanatory anchoring bias. We are currently piloting a version of

this task to test whether people update beliefs more like Bayesian or RL agents and to explore individual differences in these mechanisms. This approach offers a new computational framework for studying belief persistence, especially in clinical contexts where false beliefs are maladaptively maintained. Understanding explanatory anchoring bias may inform targeted interventions for persistent dysfunctional beliefs.
Keywords: *Belief updating, evidence integration, cognitive biases, information seeking, individual differences*

## (30). From Clicks to Curiosity: Exploring Self-Directed Information Seeking as a Behavioral Manifestation of Curiosity

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Abstract: To expand their knowledge and satisfy their intellectual curiosity, people need to engage in self-directed information seeking. However, curiosity research often relies on experimental tasks that explicitly prompt information seeking instead of capturing participants' self-initiated exploratory behaviors. The present study aimed to combine aspects of experimental curiosity research with more naturalistic exploration methods by introducing a novel experimental set-up that captured self-directed information seeking as a behavioral measure of curiosity. In a preregistered online study ($N$ = 799), participants freely explored a hypertext on a historical topic while their self-directed information seeking (i.e., clicks on hyperlinks and reading time) was captured with log files. Participants then completed a knowledge test in which they also reported their confidence in their answers and their curiosity about learning the correct answers. Additionally, participants' trait curiosity was measured with a questionnaire before they read the hypertext. Using mixed-effects regression models, we found that simply choosing to seek additional information (click on a hyperlink) did not predict subsequent curiosity ratings ($b$ = -0.002, $t$(13981.06) = -0.16, $p$ = .871), whereas the extent of engagement (reading time) did (linear term: $b1$ = -2.90, $t$(5577.40) = -3.18, $p$ = .002; quadratic term: $b2$ = 2.86, $t$(6048.21) = 2.93, $p$ = .003). Moreover, trait curiosity moderated the relationship between confidence and state curiosity, with highly trait curious individuals maintaining higher state curiosity under low confidence, unlike those with low trait curiosity. Furthermore, we found that the relationship between confidence and state curiosity varied by scaling approach with a negative linear relationship for within-person centered confidence and a negative quadratic relationship for between-person centering. This study presents a promising way to assess self-directed information-seeking behavior as a manifestation of curiosity and provides a comprehensive perspective on the dynamic ways in which curiosity is sparked and satisfied.
Keywords: *information seeking, trait curiosity, state curiosity, confidence, behavioral trace data*

## (32). Social curiosity in the brain: Examining overt and covert curiosity using an fMRI natural viewing paradigm

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**Abstract:** Social curiosity, the curiosity about others and their relationships, is an intrinsic part of human nature. Social curiosity has been found to be a unique dimension of trait-level curiosity[1–3], and data-driven factor analysis has shown that trait social curiosity consists of two unique components – overt and covert social curiosity – based on how people fulfill their social curiosity by directly or indirectly obtaining information[3,4]. However, little is known about the individual differences in trait social curiosity and its neural underpinnings. The current study aims to advance our knowledge of social curiosity by studying the neural underpinnings of overt and covert social curiosity using a naturalistic neuroimaging paradigm. In the study, 40 participants watched movies in the MRI scanner, and their social curiosity was assessed using the Five-dimensional Curiosity Scale Revised (5DCR)[3]. Preliminary analyses showed that participants of high overt social curiosity processed the video stimuli more similarly in the temporal pole of the limbic system, which has been associated with high-level cognitive processes, such as semantic and socio-emotional processing. This suggests that higher levels of overt social curiosity might lead people to understand and emotionally respond to the videos in more similar ways. In addition, we found that people who were high on covert social curiosity processed video stimuli more similarly across multiple brain regions in somatomotor, control, and default mode brain networks, which have been implicated in a wide range of processes (e.g., perception, sensory and emotional processing, and social cognition). These together suggest that higher levels of covert social curiosity may lead people to perceive, interpret, or process information more similarly. As trait-level social curiosity facilitates seeking and building connections with others, this work contributes to our understanding of the processes underlying relationship formation, which may be especially important for physical and mental health outcomes.

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**Keywords**: *social curiosity, social neuroscience, fMRI*

## (34). Dopamine Influences Risk Preference Through Learning, Not Utility Curvature

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**Abstract:** *Objective:* Risk preference can emerge from distinct cognitive mechanisms depending on the nature of outcome uncertainty. We aimed to dissociate utility-based and learning-based influences on risky decision-making and identify which mechanism mediates dopamine's effect on risk preference.

*Methods and Results:* We designed two parallel tasks where mice chose between a risky (lottery) and a certain (surebet) option on each trial. In the cued task, lottery offers are explicitly signalled, reflecting stationary stochasticity (n = 10); while in the uncued task, lottery offers are unsignaled and change in blocks, introducing volatility (n = 12). Using Cohen's partial pseudo-$R^2$ to quantify the relative contribution of different factors, we found that the current trial's offer (ΔEV = EVlottery - EVsurebet) drove choices more in the cued task (cued: 0.94, uncued: 0.77, t(15.5) = 4.19, p = 0.0007), while the previous trial's outcome (win/lose the lottery) dominated in the uncued task (cued: 0.09, uncued: 0.65, t(14.8) = -7.81, p < 1e-5), with strong win-stay/lose-switch effects. This suggests in stationary stochastic environments like the cued task, utility curvature is more important for guiding choice, whereas in volatile environments like the uncued task, learning from recent outcomes also affects choice. Pharmacological manipulation with the dopamine D2/3R agonist pramipexole (PPX) selectively increased lottery choices in the uncued task by asymmetrically reducing outcome sensitivity (a large decrease in lose-switch), but minimally affected the cued task (Δoutcome-effect: cued = 0.04 ± 0.05 SE, n = 8; uncued = -0.28 ± 0.06 SE, n = 6). These results suggest that dopamine modulates risk preference through value learning, rather than utility-based evaluation. Surprisingly, dopamine release in the nucleus accumbens, measured via dLight1 fiber photometry, tracked reward outcomes in mice doing either task (cued: n = 2, uncued: n = 1, ongoing data collection). This implies that in the cued task, while prediction error signals are intact, their influence on behavior is gated. Ongoing work using optogenetic manipulations, neural recordings, and computational models integrating reinforcement learning and expected utility theory aims to mechanistically explain how learning can be behaviorally decoupled from dopamine signals.

*Conclusions:* Together, these findings outline distinct cognitive and neural mechanisms underlying risky decision-making and better characterize the contribution of dopamine. This may help with developing differential diagnoses for maladaptive risk-related behaviors like pathological gambling.

**Key words:** *D - Risk & Uncertainty; I - Valuation & Decision Making; H - Learning & Memory*

## (36). Linear and Non-linear Goal-dependent Relationships Between Overall Value and Response Times in Decision-Making

*Chih-Chung Ting*[1], Romy Froemer[2], Jason Leng[3], Amitai Shenhav[3], Sebastian Gluth[1]

[1]University of Hamburg, [2]University of Birmingham, [3]University of California, Berkeley

**Abstract:** Humans exhibit flexibility in how they search for information and make choices to align with different decision goals. One possible mechanism underlying this flexibility is the transformation of option values from preference-based to goal-congruent

representations. Previous studies support this view, showing that the relationship between the overall value (OV) of the available options and response times (RTs) is modulated by the current decision goal: people tend to make faster decisions when choosing between goal-congruent options than goal incongruent options. However, these studies mainly focused on two decision goals—choosing the best or worst option—their findings only suggest that values are transformed linearly. Consequently, it remains unclear whether such value transformations can be non-linear under certain goals, such as choosing the most mediocre or extreme option. We conducted a within-subject online experiment that included four-block choice task (N=46). In each block, participants made decisions based on one of four decision goals: choosing the best, worst, most mediocre, or most extreme option. In each trial, participants chose one product from sets of four. The order of blocks was counterbalanced across participants. Regression analyses revealed that choices were fastest when the overall value of the options was closest to the target for the choice goal. Specifically, replicating previous findings, RTs decreased with increasing/decreasing OV when the target was to choose the best/worst option (best: $\beta$=-0.08±0.00, p<.001; worst: $\beta$=0.13±0.00, p<.001). Importantly, participants responded fastest at intermediate OV level when the target was to choose the most mediocre option (positive quadratic effect: $\beta$=0.02±0.00, p=.030). This U-shape relationship between RTs and OV was reversed in the extremity condition − responses were fastest when OV was at either end of the rating scale (negative quadratic effect: $\beta$=-0.04±0.00, p<.001). Together, our findings suggest that flexible decision-making relies on goal-dependent value representations that can be transformed in both linear and non-linear ways.

## (38). Computational measures of metacognition for risk and their relation to emotional monitoring and control

*Justine Trudeau*

National Institute of Mental Health

Abstract: *Background.* Awareness of one's emotions and the quality of one's decisions guides behavior. Metacognitive monitoring of decision-making and emotional state monitoring are examples of different kinds of awareness, but the extent to which these traits are similar is not yet fully understood. Here, we employ a recently developed computational model of confidence to evaluate how metacognition for risky decision-making relates to emotional awareness and control.

*Methods*. 69 adults completed a confidence and decision-making under uncertainty task. Participants chose between a monetary gain or loss of $5 with 100% probability versus a lottery to win or lose a different amount (or nothing). The lottery amounts, probabilities, and ambiguity levels (0% for risk trials) varied trial-by-trial. After making their choice, participants rated their confidence that they chose what they preferred. We sequentially fit a utility model to the task choices and the CASANDRE model of confidence to high versus low confidence ratings, using Maximum Likelihood Estimation with PyTorch. CASANDRE returned individual parameters for meta-uncertainty, a computational measure of metacognitive ability, and confidence criterion. Participants completed the Interoceptive Accuracy Questionnaire, Trait Meta-Mood Scale, Toronto Alexithymia Scale, Mindful

Attention Awareness Scale, General Self-Efficacy Questionnaire, Emotion Regulation Questionnaire, and the Ego-Resiliency Questionnaire. Confirmatory factor analysis (CFA) compared a one- versus two-factor model containing all questionnaire scores as factors. *Results.* The 2-factor CFA explained more variance and out-performed the 1-factor CFA based on scree plot, comparative index, and AIC measures. Factor loadings for factor 1 predominantly represented emotional awareness and monitoring; factor 2 loadings corresponded to emotional regulation and control. We found no significant associations between metacognitive ability and CFA factors. Factor 1 (Emotional Awareness) exhibited a trending but negative association with the metacognitive ability parameter (rho=-0.22, p=0.064) while factor 2 (Emotional Control) was not associated with metacognition (rho=0.15, p=0.212).
*Conclusions.* Our results indicate that emotional awareness is a separable construct from emotional control. Surprisingly, higher self-reported emotional awareness seemed marginally related to worse metacognitive ability for risky decision-making, perhaps suggesting that attention to internal states versus cognition are two opposing aspects of awareness. Follow-up studies will attempt to replicate this result in a larger online sample.
**Keywords:** *J - Emotion; I - Valuation & Decision Making; D - Risk & Uncertainty*

## (40). Preschoolers persist more when effort-based messages align with effort-based rewards

*Elaine Wang*, Mia Radovanovic, Jessica Sommerville, Julia Leonard

**Abstract:** Children are frequently exposed to mixed messages about the value of effort: Educators talk about the importance of effort, but give rewards (e.g., grades) based on achievement. How do these different messages about the value of effort influence children's persistence?

In Experiment 1 ($N$ = 80), we presented 4- to 5-year-old children with a verbal message preaching the importance of effort and rewarded participants for their effort (trying time) or performance (items found) across iSpy trials. Persistence (trying time) was measured during the iSpy trials and on a novel task (impossible puzzle box) to assess whether effects would generalize when no rewards were offered. We found that children were more persistent when exposed to verbal- *and* reward-based messages about the value of effort on the immediate task ($\chi^2(N = 80) = 8.47$, $p = .004$), and on the transfer task ($W = 537$, $p = .01$).

In Experiment 2 ($N$ = 200), we investigated mechanisms underlying the effects from Experiment 1 by manipulating both the initial verbal message (preaching effort or performance) and the reward structure in the iSpy games. Participants persisted longer when effort (vs. performance) was verbally emphasized and rewarded in the iSpy games ($\chi^2_{message}$ ($N$ = 200) = 6.35, $p = .01$; $\chi^2_{reward}$ ($N$ = 200) = 11.22, $p < .001$), with effects generalizing to the transfer task ($\beta_{message} = 57$, $p = .002$; $\beta_{reward} = 23$, $p = .04$), suggesting that children *integrate* effort-based verbal messages and rewards to guide their motivated behavior.

These results provide causal support for the 'seed and soil' hypothesis from the mindset literature: For messages about the value of effort (the seed) to be impactful, they should be paired with supportive incentive structures (the soil). Critically, rewarding effort may

inform children's broader beliefs about their learning potential that transcends the immediate context, subsequently shaping exploration and curiosity to persist on future challenging problems.

Keywords: *persistence, exploration, social learning, adult testimony*

## (42). Humans Explore by Learning to Reinforcement Learn: An Online Gradient-Based Account

*Hua-Dong Xiong* (School of Psychology, Georgia Institute of Technology), Li Ji-An (Neurosciences Graduate Program, University of California San Diego), Marcelo G. Mattar (Department of Psychology, New York University), Robert C. Wilson (School of Psychology, Georgia Institute of Technology)

Abstract: A hallmark of human intelligence is the ability to adapt learning strategies in response to changing environments. In value-based decision-making, this involves not only learning action values but also developing effective exploration strategies—a core component of curiosity and information-seeking behavior. We investigate whether humans learn to explore by dynamically adapting their reinforcement learning (RL) strategies over time, and whether this process resembles gradient-based meta-learning. Using a novel modeling framework, DynamicRL, we estimate how individuals adjust RL parameters such as learning rate and decision stochasticity during sequential decision-making. Across four multi-armed bandit tasks, we show that DynamicRL better explains behavior than models with fixed parameters and reveals that participants continuously refine their strategies over the course of an experiment. Crucially, we find that humans improve task performance by discovering more effective exploration strategies in real time. The directions of their RL parameter updates align with policy gradient ascent, suggesting that humans adapt by ascending the reward landscape in parameter space. This adaptation process supports a two-level reinforcement learning mechanism, where participants learn action values while simultaneously learning how to learn—i.e., how to explore more effectively. Beyond empirical findings, we propose a theoretical framework that characterizes adaptive behavior as online gradient descent in a learned representation space, unifying reinforcement learning and heuristic exploration under a common computational principle. Taken together, our findings support a gradient-based meta RL hypothesis: humans explore not only by selecting rewarding actions, but by learning to optimize their own learning strategies. This framework offers a new perspective on adaptive behavior, linking exploration and decision-making to optimization in strategy space.

Keywords: *Reinforcement Learning · Meta-Learning · Exploration · Cognitive Modeling*

## (44). Does information-seeking motive explain belief inflexibility in psychosis-proneness?

*Wanchen Zhao*, Tyrone Cannon

Yale University, Department of Psychology

Abstract*: Background.* Cognitive models of delusions emphasize the role of belief updating impairment in maintaining false beliefs, but sources of this tendency remain unclear. While belief inflexibility can be explained by impairments in neurocognitive systems supporting

evidence integration, lower information seeking motive could also lead to disregard for new evidence once a false belief is formed.
*Methods.* The final sample consists of 137 MTurk participants. In the Interpretation Inflexibility Task (IIT), participants viewed social scenarios and rated the plausibility of different explanations, as more information was revealed. Participants could skip seeing information if confident of their ratings. In the Stock Market Task (SMT), participants viewed a global market, estimated their current gain or loss, rated confidence, and indicated their need for information. Psychosis-proneness was measured with Multidimensional Schizotypy Scale – Brief.
*Results.* A mixed effect regression showed that participants higher in positive schizotypy only sought out more information when highly confident of their estimation on SMT. A robust regression showed that belief flexibility associated positively with information skipping on IIT, meaning that occasional information skipping was associated with better belief flexibility on scenarios with information fully pursued. Participants with higher positive schizotypy showed less belief flexibility and skipped more information on the IIT. The interaction between positive schizotypy and information skipping was not significant.
*Conclusions.* Participants with higher psychosis-proneness showed a heightened self-confirmatory information seeking tendency, potentially contributing to an "echo chamber" with fewer opportunities to correct false beliefs. The counter-intuitively positive effect of information skipping suggests motivation as a facilitator of belief flexibility – voluntarily seeking information requires more motivation in an "information skipper". However, differences in information-seeking motive did not explain impaired belief flexibility among those prone to psychosis.
Key words: *overconfidence, belief flexibility, psychosis-proneness*

# Session 2: Wednesday, October 1, 1:15 - 2:45

### (1). The Role of Prior Knowledge in Age-Related Differences in State Curiosity

*Mats Abrahamse*[1], Alexandr Ten[1], Kou Murayama[12], & Michiko Sakaki[12]
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Abstract:
Older adults often report higher levels of state curiosity than younger adults (Fastrich et al., 2024; Whatley et al., 2025). The reasons for this age-related difference remain unclear, even though promoting curiosity may be important for healthy aging (Sakaki et al., 2018). One potential explanation for this age-related difference in state curiosity is prior knowledge, which typically increases with age (Coane & Umanath, 2021) and positively affects state curiosity (Murayama, 2022). To investigate this explanation, we conducted two preregistered experiments in which younger and older adults rated their curiosity to learn answers to trivia questions in low- and high-knowledge domains. In Experiment 1 (N = 216), our main aim was to examine the age effect in the domains where older and younger adults are likely to have comparable knowledge. Our findings showed strong knowledge effects on curiosity in both age groups. There were also significant age effects on curiosity, with older adults scoring higher than younger adults, but these effects were significantly

smaller than the effects of knowledge. In Experiment 2 (N = 216), we controlled for age differences in prior knowledge by selecting trivia questions for which younger and older adults provided overall statistically similar knowledge ratings in a pilot study. In contrast to Experiment 1, participants also had the opportunity to search for additional information. As in Experiment 1, we observed strong knowledge effects on curiosity; in contrast, there was no significant age-related difference in curiosity. Furthermore, there were strong knowledge effects on information seeking. Interestingly, there was also a small age effect, with younger adults searching for more information than older adults. These findings suggest that prior knowledge is an important factor for state curiosity across adulthood and may explain previously observed age differences in state curiosity.

**Keywords:** *State Curiosity, Trivia Questions Paradigm, Aging, Epistemic Curiosity, Prior Knowledge*

## (3). Progesterone Withdrawal in an Animal Model of PMDD: Is it Anxiety or Risk Aversion?

*Prisha R. Bharadwaj*, Diego Lievano Parra, Christina A. Davis, Sun Kim & Valeria V. González
Reed College

**Abstract:** Premenstrual Dysphoric Disorder (PMDD) is a psychiatric disorder that severely affects moods and behaviors of around 5-8% of menstruating individuals[1]. A potential explanation relies on hypersensitivity to the drop in progesterone levels[2]. PMDD models in rodents use progesterone administration (PA) followed by withdrawal (PWD). Prior experiments use ovariectomized rats, removing the effect of hormonal variability. We proposed to mimic PMDD using the described model in naturally cycling rats and evaluate its impact on decision-making and anxiety. Eight female rats (Long-Evans) received vaginal swabs with cytological analysis for 12 days. Then, rats received two courses of PA (5 mg/kg, i.p., for 4 and 5 days, respectively). During the 24-48 hours of PWD rats received vaginal swabs, and their behavior was determined using the Light-Dark Box (LDB) and Elevated-Plus Maze (EPM). Two weeks later, rats were tested on LDB and EPM to establish baseline behavior. Results showed that in LDB, rats tended to spend more time in the dark box after PWD than during baseline *($t(6) = 2.29$, $p = 0.06$)*. On the EPM, the opposite was observed; rats spent more time in the closed arms during baseline than after PWD (*$t(6) = -2.12$, $p = 0.08$*). As rats were measured on the EPM 24 hours after the LDB, their cycle generally shifted from proestrous to estrous (i.e., luteal-to-menstrual in humans), it hints to the alleviation of anxious symptoms and/or risk aversion after the proestrous stage. Thus, PWD may be linked to decreased risk-aversion/increased anxiety during the proestrous/luteal phases, but linked to increased risk aversion/decreased anxiety during the estrous/menstrual phases. Future experiments will expand this result with a larger sample size to account for cycle variability and include behavioral tests that allow us to disentangle anxiety from risky decision-making.

**Citations:**

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**Key Words:** *premenstrual dysphoric disorder, progesterone withdrawal, anxiety, risky decision-making*

## (5). Aging, Motivation, and the Blue Spot: Locus Coeruleus Contributions to Information-seeking

*Hsiang-Yu Chen*[1], Emma L. Carlson[1], Johanna L. Matulonis[1], McKenna S. Costello[1], Alex A. Adornato[1], Katherine E. O'Malley[1], Heidi I. L. Jacobs[2], Jacob M. Hooker[2], Anne S. Berry[1]

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**Abstract:** Curiosity is a key driver of learning and memory and has been linked to the function of the locus coeruleus (LC). However, little research has examined how curiosity changes with age, its impact on memory, and its association with LC structure and function. To examine these questions, we developed the Photographic Art Storytelling Task. Participants viewed photographs, rated their curiosity, and later read stories associated with selected images. The stories were deliberately constructed to be either interesting or boring, functioning as rewards that elicited prediction errors. Participants then reappraised their curiosity, allowing us to separate intrinsic motivation from story-driven reward influences. A total of 133 participants (65 older and 68 young adults) completed the task, with 35 older undergoing 3T and 43 young adults undergoing 7T LC structural MRI. Results revealed age differences in information-seeking strategies. Young adults' information-seeking was more strongly shaped by story content, suggesting a reward related prediction error mechanism. Older adults appeared to rely more on their initial feelings of curiosity, indicating a greater sensitivity to novelty. We also observed age related differences in curiosity arousal and engagement, as reflected in pupillary responses. In young adults, pupil dilations positively correlated with curiosity ratings, suggesting that curiosity enhances anticipatory arousal in response to upcoming information. In contrast, older adults showed that lower curiosity ratings were associated with larger pupil dilations, potentially reflecting an aversive or disengaged response to less interesting stimuli. Importantly, individuals with greater LC integrity were less influenced by story content, suggesting LC involvement in curiosity regulation. Curiosity enhanced memory in both age groups. Together, these

findings indicate that curiosity enhances episodic memory, which is consistent with accounts that motivational factors may support the successful maintenance of cognitive function in aging. The LC appears to regulate curiosity-based information-seeking, presenting a potential target for promoting healthy cognitive aging.
Keywords: *curiosity; information-seeking; locus coeruleus; aging*

## (7). Non-neuronal Modulation of Cognitive Flexibility: ACC Astrocyte Activation Enhances Learning but Not Mastery in Reversal Learning

*Christina A. Davis*, Diego Lievano Parra, Prisha R. Bharadwaj, Sun Kim & Valeria V. González

Abstract: Cognitive-flexibility is impaired across a range of neurological and psychiatric conditions, including neurodegenerative diseases, mood disorders, and chemotherapy induced cognitive impairment 3. While neuronal dysfunction has been the focus of research into these deficits, increasing evidence suggests astrocyte modulation in it 2. Astrocytes play a role in synaptic homeostasis and neuroinflammation, yet their contribution to higher-order cognitive functions remains poorly understood1,4. In this study, we investigate the role of astrocyte activation in the anterior cingulate cortex (ACC) in cognitive-flexibility. Long-Evans rats (N=14) were assigned to an experimental or control group. The former received excitatory Designer Receptors Exclusively Activated by Designer Drugs (DREADDs) in the ACC (AAV8-GFAP-hM3Dq-mCherry). Rats were trained on a deterministic reversal learning task: one lever was rewarded in block one, with contingencies reversed in block two. Animals required ≥70% accuracy in both blocks to complete the task. The experimental group received DCZ prior to each session for DREADD activation. Preliminary data showed that rats with astrocyte activation in ACC reached criteria in fewer sessions compared to controls, with a marginally significant difference (Welch's $t(10.05)= 2.17$, $p = 0.056$), suggesting an enhanced learning speed. However, this group also exhibited reduced accuracy across both blocks compared to the control ($M_{experimental}= 78.5$, $M_{control}= 83.9$). Error pattern analysis revealed that control rats made most errors around the reversal point, whereas the astrocyte-activated rats showed a broader error distribution, indicating increased exploratory and earlier sampling before the reversal. These findings suggest that while astrocyte activation facilitates learning, it may do so at the cost of accuracy, possibly through increased impulsivity or heightened synaptic plasticity. This synaptic plasticity may disrupt the development of a model-based strategy by sustaining an exploratory, model-free behavioral strategy. Ongoing work includes a probabilistic reversal learning paradigm and immunohistochemistry to examine markers of synaptic plasticity.

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https://doi.org/10.3390/biom14101204
**Key words:** *Astrocytes, Cognitive Flexibility, Reversal learning, Anterior cingulate cortex (ACC)*

### (9). Seeking information from compassionate code: AI compassion increases information seeking but not learning

*Amber Duettmann*

**Abstract:** *Objective:* Humans turn to AI systems (LLMs) daily for information. How does AI's tone influence our desire to seek information and ability to process it? Theory suggests we are more likely to want information when we expect it to improve our understanding and mood (Sharot & Sunstein, 2020). Those factors may also be associated with how well we learn information. Because an AI's tone (particularly social-emotional tone) may impact humans' subjective understanding and mood, it may in turn impact information seeking and learning. We examine if and how AI's perceived tone affects humans' tendency to seek and learn from information.
*Methods:* 206 subjects completed a multiple-choice exam before and after receiving feedback from an AI system (GPT-4o). They reported their mood and subjective understanding before and after receiving feedback and indicated whether they wanted more information about the topic. Feedback was generated multiple times per question using the prompt: "I think the correct answer to the question below is {answer}. Is this correct?". The responses varied in tone but were always accurate. Subjects thus received different feedback and rated their perception of it on empathy, politeness, helpfulness, bluntness, and confrontational tone.
*Results:* After interacting with the AI, subjects improved on the exam ($t(205)=7.64$, $p<.001$) and indicated they wanted to learn more ($t(205)=5.51$, $p<.001$). Dimensionality reduction analysis of the ratings produced a component explaining 32% of variability. This component, which we labelled "perceived compassion", had high weights on empathy, politeness, helpfulness; a negative weight on bluntness; and zero weight on confrontation. Importantly, we found that greater perceived compassion was related to greater information seeking ($\beta=11.25$, $p<.001$), improved mood ($\beta=2.10$, $p=.05$) and enhanced feeling of understanding ($\beta=9.30$, $p<.001$). In contrast, it was not associated with changes in exam scores ($\beta=0.01$, $p= .31$, $R^2=.01$). The increase in information seeking was mediated by improved mood (ACME=1.38, $p=.036$) and subjective understanding (ACME=3.05, $p<.001$).
*Conclusion:* Compassionate AI increased information seeking by enhancing mood and a feeling of understanding, but not learning per-se. This demonstrates a dissociation between factors that increase information seeking (and subjective understanding) and those that increase objective learning. Understanding this dissociation is important for theoretical models of learning and for developing AI that not only engages people but also facilitates accurate learning.

## (15). Individual differences in dynamic belief updating during trust learning

*Valentin Guigon 1*, Selin Topel 2, Caroline Charpentier 1,3

1: University of Maryland; 2: Leiden University; 3: Brain and Behavior Institute

**Abstract:** *Objective.* Trust involves decisions made under uncertainty whereby outcomes depend on the unobservable intentions of others. Unlike natural risk, this uncertainty is relational and contingent on inferred partner reliability. While normative models assume people update beliefs about others based on outcomes, individuals vary in their strategies and sensitivities - especially in populations with social cognitive difficulties. This study aims to characterize individual differences in trust updating and underlying computational mechanisms.

*Methods.* We studied this heterogeneity using an online repeated trust game, in which participants (N=334, ages 18–65) acted as trustors allocating portions of an endowment to one of two computer-controlled agents. Investments were multiplied by 4, and reciprocation varied dynamically across time. To isolate learning mechanisms from the influence of social context, agents were either framed as humans (social condition) or slot machines (nonsocial condition), with matched contingencies and volatile changes in trustworthiness. To characterize latent cognitive profiles, we fit multiple classes of models that varied along two axes: policy structure and trustworthiness estimation process. Policies included heuristic (Win-Stay-Lose-Shift, constant investment), softmax action selection and linear proportional adjustments. Trustworthiness estimation models ranged from static expectations (no learning or mentalizing) to Reinforcement Learning (RL; trial and-error value updating), to Bayesian models (beliefs tracking with uncertainty).

*Results.* Results showed that participants adapted their investments based on partner reciprocity, but asymmetrically. Monetary losses caused stronger trust changes than gains, resulting in steeper scaling of subsequent sharing following losses. This asymmetry was more pronounced in the social condition, with slower trust recovery following violations by initially trustworthy human partners. Preliminary modeling supports cognitive heterogeneity in trust learning: while RL models fit group-level data well, individual-level variations were best captured by considering multiple policies and trustworthiness estimation algorithms rather than a 'best-model-fits-all' approach.

*Conclusions.* By examining individual differences in model fit and parameter estimates, our findings highlight unique cognitive signatures of trust learning strategies and policy choices across social contexts. Next steps include testing whether these cognitive profiles map onto traits and symptoms traditionally associated with social dysfunction.

**Keywords**: *Game Theory & Strategic Interactions, Individual & Lifespan Differences, Risk & Uncertainty*

## (17). Role of Prediction Error Precision in Modulating Epistemic Foraging under Active Inference

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**Abstract:** Navigating the world effectively requires a balance between goal-directed (pragmatic), and information-seeking(epistemic) behaviors, particularly when faced with

varying degrees of uncertainty. Importantly, the reliability of the prediction signal (precision) plays an important role in determining the optimal decision-making strategy. While reward prediction error's (RPE) relevance to updating value is well established, how the precision-weighted signal influences subsequent foraging behavior is less understood. This study models sequential decision-making under uncertainty using a partially observable Markov decision process (POMDP), where an agent must make inferences about the hidden state of an environment, by continually predicting the sensory consequences of its actions. To investigate the influence of precision-weighted signals, two forms of prediction errors are manipulated by contrasting ambiguous reward omission errors (low-precision RPEs) and unambiguous predicted sensory feedback errors (high-precision sensorimotor prediction errors, or SMPEs). We hypothesized that the ambiguity of prediction information would determine persistence of uncertainty, leading to prolonged, quantifiable changes in epistemic behavior. Indeed, agents that experienced the ambiguous, low-precision signals engaged in prolonged epistemic actions. Driven by residual uncertainty within their internal model, agents were unable to confidently disambiguate the causes of the reward omission. In contrast, agents that first experienced the unambiguous, high-precision SMPE rapidly resolved their uncertainty, allowing them to utilize a more optimal decision policy, and use pragmatic behavior to accrue more reward. These findings provide an account of inferential processes the brain may use to reliably weigh sensory evidence to modulate policy selection. This demonstrates that persistent, seemingly maladaptive exploration can emerge as a rational consequence of trying to explain ambiguous data. This reframes the role of surprise minimization, suggesting that its influence on behavior is not determined just by magnitude, but by its weighted impact on an agent's subjective belief about the world.

Keywords: *Active Inference, Epistemic Foraging, Prediction Error Precision, Uncertainty, POMDP*

## (19). Daily Brooding Moderates the Relationship Between Information-Seeking and Anxiety

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Abstract: *Background.* Anxiety is associated with greater information-seeking behavior during major societal shifts, such as pandemics, when uncertainty and perceived threats are high. While this behavior can serve an adaptive purpose (e.g., helping individuals regain a sense of control), it can also lead to maladaptive outcomes (e.g., exposure to distressing

content that exacerbates anxiety). Emotion regulation may play a pivotal role in shaping whether information-seeking serves a beneficial or harmful function. However, the dynamic relation between anxiety, information-seeking behavior, and emotion regulation remains inadequately investigated. This study examines how brooding (passive and repetitive focus on causes, consequences, and symptoms) and dampening (downplaying of positive emotions, thoughts, or experiences) might moderate the relationship between anxiety and information-seeking behavior.
*Methods.* Using a 28-day daily diary design during early COVID-19 (March-April 2020), we monitored 205 U.S. participants (62% White, 20% Black, 7% Asian, 3% Native American, 6% Hispanic) who reported daily anxiety levels, information-seeking behavior, and emotion regulation strategy use across 4,281 completed surveys. Linear mixed effects modeling showed that higher daily anxiety levels were associated with more time spent seeking COVID-19 information.
*Results.* Brooding but not dampening moderated this association, weakening the anxiety and information-seeking relationship on days when individuals engaged more in brooding. Simple slope analysis revealed that on high brooding days participants exhibited elevated anxiety regardless of information-seeking duration, while on low brooding days, daily anxiety levels increased with greater information-seeking.
*Conclusion.* To our knowledge, this is the first study to integrate emotion regulation strategies into daily-level research of information-seeking and anxiety. These findings challenge the assumed universality of the positive information seeking-anxiety relationship and provide theoretical implications for understanding the complex role of emotion regulation in moderating when information-seeking becomes more maladaptive.
Keywords: *information-seeking, emotion regulation, anxiety, daily diary method*

### (21). Internal Error Signals and Noradrenergic Neuromodulation Shape Escape Decisions in a Fear of Heights Task

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Abstract: Adaptive decision making requires integration of prior experience and changing internal states. We developed a task in which mice face an innately threatening height stimulus [1] and must decide on an appropriate exit direction. This task elicits robust, untrained behaviors in a continuously tunable paradigm (Figure 1). Using optogenetics, we found that the locus coeruleus (LC) and its noradrenergic projections to the medial prefrontal cortex (mPFC) are necessary for task performance (Figure 2A). A generalized linear mixed model (GLMM) revealed that prior outcome, gated by stimulus type, predicted next trial accuracy (Figure 2B); further analysis confirmed that this post-error boost only occurs in tall trials ($p=0.029$), consistent with error monitoring in both attentional and aversive assays [2,3]. We thus hypothesized the existence of error signals in this circuit. LC inhibition impaired accuracy and abolishes the post-error boost (Figure 2C), while mPFC inhibition reduces accuracy without eliminating post-error boosts (Figure 3C). This suggests that the error signal is noradrenergic in origin but not stored in PL PFC, somewhat consistent with prior literature on other cortical storage of attentional task error signals [2,3] and noradrenergic representation of threat prediction error signal [4,5] To dissect internal

states, we fit a 2-state hidden Markov model (HMM), identifying 'engaged' and 'disengaged' latent states. State transitions corelated with prior errors (p=0.009), and 'engaged' occupancy decreased with trial number (p<0.005). These latent states were not correlated to stimulus ambiguity (p=0.722), suggesting that internal state dynamics, rather than task features, shape fear-driven adaptive behaviors. Our findings point to a noradrenergic mechanism for tracking internal error signals and modulating decision policies in high-stress contexts. Future directions include latent state modeling of norepinephrine fiber photometry, as well as prefrontal ensemble dynamic analysis to identify neuronal populations encoding internal states and guiding decisions.

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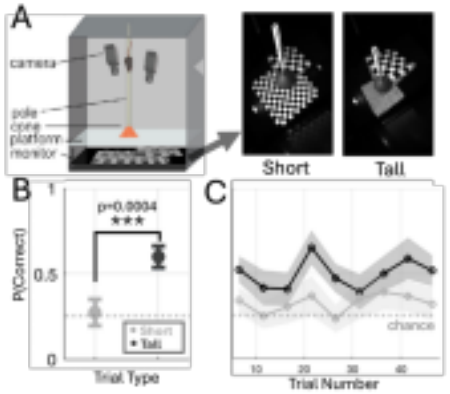


*Figure 1: Virtual Pole-Descent Heights Task. (A) Task schematic and monitor images for each trial type. (B) Mice prefer the "safe" or correct quadrant when the trial type is tall. (C) Task performance is relatively stable over 50 repeated trials.*

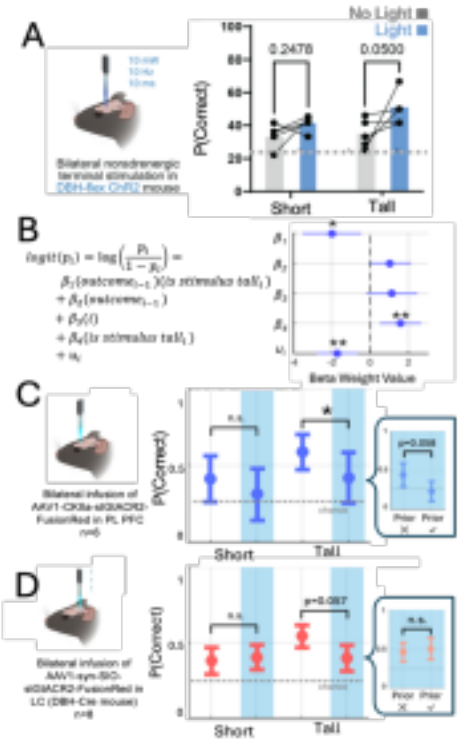


*Figure 2: Task outcomes rely on a noradrenergic circuit. (A) Optogenetic stimulation of noradrenergic terminals in PL PFC. (B) Generalized linear mixed model with a random intercept (u) capturing inter*
*mouse variability ($\sigma_u$=0.29). (C-D) Optogenetic inhibition of PL PFC and LC, respectively. Insets show inhibition on tall trials separated between prior incorrect and prior correct trials.*

**Key Words:** *Norepinephrine, decision-making, neuromodulation, error signals, internal states*

## (23). The effects of across-trial lottery-outcome variance on gaze and choice

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**Abstract:** *Objective:* There is an established link between how long people look at option attributes and how much they weight those attributes in their choices (Yang & Krajbich, 2023). But what drives attention to different attributes? It is thought that people allocate their limited cognitive resources to maximize information gain, focusing on features deemed most relevant based on learning and environmental statistics. Thus, according to several prominent theories, decision-makers should focus on reducing their uncertainty about high-variance (i.e., salient) attributes. This may lead them to overweight those salient attributes (Bordalo et al., 2012). Prior research has examined salience in static, within-choice contexts, where uncertainty aversion may counteract the hypothesized effect. Here, we investigated whether across trial variability in gamble attributes could influence gaze and, consequently, risky decision-making
*Method:* Participants made a series of 300 choices about whether to accept or reject a three-outcome equiprobable gamble. From one choice to the next, the outcomes were

drawn from distributions with different variances. In the treatment group, the three outcome distributions had low (sd = 4), medium (sd = 28.4 ), or high (sd = 40) variance. By contrast, the control group experienced the same set of gambles, but with half of the low-variance outcomes swapped with half of the high-variance outcomes, making it so that each outcome distribution had the same medium variance.
We measured participants' choices, response times and visual attention using an Eyelink 1000 Plus eye tracker.
*Results:* Contrary to predictions, participants in the treatment group spent more time looking at, and placed more weight on, the low variance location. Participants in the treatment group were more likely to accept risky gambles than those in the control group ($\beta$treatment = 0.868, SE = .408, z = 2.129, p = .033). Additionally, there was a significant interaction between treatment and low variance outcome ($\beta$low x treatment = 4.189, SE = 1.759, z = 2.382, p = .017), indicating that participants in the treatment group weighted low variance outcomes more heavily than participants in the control group. The interaction for high-variance outcomes was marginal ($\beta$high x treatment =2.045, SE=1.056, z=1.933, p = .053), indicating a trend toward increased weighting of the high-variance outcomes among treatment group participants relative to control group participants. Eye-tracking largely data mirrored the choice results: participants in the treatment group fixated longer on low-variance outcomes compared to the medium (t(143) = 4.863, p <.001, 95%CI=[.011, .026]) and high variance outcomes (t(143) = 6.886, p <.001, 95%CI=[.017, .030]), indicating a shift in attentional focus toward less variable outcomes.
*Conclusion:* We used eye-tracking to investigate how gaze patterns relate to across-trial variance and risky choice. Our findings suggest that attribute salience is not solely determined by immediate, within choice contrasts, but can also be shaped by how attributes vary across time. Surprisingly, people allocate more attention to, and put more weight on, lower variance outcomes.
**Keywords:** *Attention, Decision-Making, Uncertainty, Salience*

## (25). Hidden Costs of Dopamine Loss: Temporal and Sex-Specific Impairments in Reversal Learning after SNc Lesion

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**Abstract:** Learning, Substantia Nigra Compacta (SNc). Reversal learning (RL) refers to the flexible updating of behavior in response to changing contingencies[1] and it is impaired early in Parkinson's disease (PD)[2]. While animal models show that dopaminergic loss in the nigrostriatal pathway impairs RL[3,4], it remains unclear whether action-based (AB) and stimulus-based (SB) are equally affected[5], or how these deficits evolve over time following lesions to the substantia nigra compacta (SNc). This study aimed to determine whether 6-hydroxydopamine (6-OHDA) infusion into the SNc impairs performance in deterministic RL tasks, and to examine whether the timing of evaluation modulates cognitive flexibility after dopamine depletion. 102 male and female Wistar rats received unilateral infusions of 6-OHDA or saline into the SNc. Animals were assigned to three cohorts that began training in AB and SB-RL tasks at two, four, or six weeks post-lesion. In the AB task, one of two nose-

poke holes was rewarded regardless of cue light location; during reversal, the reward contingency switched sides. In the SB task, the illuminated cue indicated the correct hole, and post-reversal, the opposite hole was correct. Learning criterion was defined as ≥75% correct responses in 50 consecutive trials. No significant differences were found during AB discrimination or reversal, nor during SB discrimination. However, during SB reversal, 6-OHDA significantly reduced the probability of reaching criterion ($\beta$ = –3.58, SE = 1.32, p = 0.007), particularly in lesioned females ($\beta$ = 4.43, SE = 1.65, p = 0.007). A treatment × time interaction ($\beta$ = 3.69, SE = 1.76, p = 0.036) suggested attenuation of impairment at four weeks post-lesion. These findings suggest that nigral dopaminergic lesions induce temporally specific, sex dependent deficits in SB tasks, with apparent recovery at later stages potentially reflecting transient compensatory mechanisms. This model captures early Parkinsonian dysfunction and underscores the importance of identifying critical windows for cognitive vulnerability.

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**Key words:** *Parkinson's Disease, Dopamine, Cognitive Flexibility, Reversal*

## (27). Non-Instrumental Information-Seeking and Curiosity

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**Abstract:** Information-seeking helps maintain an internal model of the environment by updating beliefs about how actions lead to outcomes. In contrast to instrumental information, which facilitates goal-directed action, non-instrumental information offers a rare window into the intrinsic value of knowledge itself. People sometimes give up rewards to access information that will not affect outcomes—such as seeing foregone results or receiving earlier feedback—possibly to reduce uncertainty about the environment as a whole. In such contexts, this kind of information-seeking is often interpreted as random exploration, driven by uncertainty about the environment as a whole, rather than the

outcome of a specific decision. However, it remains unclear what kinds of non-instrumental information people are most drawn to—particularly when curiosity, rather than utility, is the driving force. This study compared the selection of two forms of non-instrumental information: procedural (i.e., quantitative information related to an outcome) versus epistemic (i.e., answers to trivia questions) in a two-choice gambling task. Following each choice between the two options, participants were presented with the opportunity to view non-instrumental information unrelated to reward outcomes. In Experiment 1, participants initially selected non-instrumental information at high rates, but their selections declined across blocks. Crucially, this selection occurred both before and after reward feedback, challenging the idea that anticipation alone drives non instrumental information-seeking. In Experiment 2, participants showed a stronger and more persistent preference for epistemic information, with selection rates less influenced by time-on task compared to the procedural group. These findings suggest that even information without instrumental value in a task-specific sense may serve broader psychological functions, revealing how different forms of curiosity engage with distinct types of uncertainty.
**Keywords:** *curiosity, non-instrumental information, information sampling, information demand, epistemic information*

## (29). Anterior Cingulate Cortex Function as Active Inference

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**Abstract:** The anterior cingulate cortex (ACC) is central to adaptive decision-making, integrating information about uncertainty, expected outcomes and the need for cognitive control. It has been widely associated with conflict detection, error monitoring and value-based learning. However, recent theoretical perspectives propose that the ACC also plays a key role in resolving the exploration–exploitation trade-off, supporting foraging-like decisions that weigh the benefits of gathering new information against exploiting known outcomes. While reinforcement learning (RL) models have provided valuable insights into ACC function, they may offer a limited account of the exploratory and uncertainty-driven aspects of control. In contrast, active inference offers a generative framework in which decisions are guided by the minimization of expected free energy, incorporating both epistemic (information-seeking) and pragmatic (reward-driven) value. This study proposes to model the ACC as a system that modulates policy precision within an active inference framework. Building on Akam et al. (2021), who demonstrated that the ACC encodes state predictions and supports model-based control in a modified two-step task, this study aims to extend those findings by comparing a classical RL account with an active inference formulation of ACC function. We will analyze data from the two-step task and a probabilistic reversal learning paradigm, reframed within an Active Inference model. This approach will assess whether Active Inference more comprehensively captures ACC-mediated behavior, particularly in volatile contexts requiring dynamic control and uncertainty resolution.
**Keywords:** *anterior cingulate cortex, active inference, exploration-exploitation*

## (31). Hungry for information: Boredom-driven exploration and its neurocognitive mechanisms in humans and mice

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**Abstract:** Boredom is a ubiquitous human experience that has been defined as an aversive mental state, typically induced by monotonous environments. While boredom is thought to drive exploration and creativity under physiological conditions, it can also promote maladaptive behaviors in psychopathologies such as ADHD, where patients often suffer from chronic boredom. Despite these psychosocial implications, the neurocognitive underpinnings of boredom and their specific role in information-seeking remain unclear. In our work, we address this issue by developing a non-verbal behavioral choice paradigm to quantify individual boredom under defined environmental conditions. With this task, we investigate boredom-related behavior in humans and mice, and combine this assay with large-scale calcium imaging in the mouse auditory cortex. Across species and task modalities, we find that the amount of sensory information, measured as empirical entropy, is a key driver of boredom-related exploration. In human subjects, we further observe that a reduced sensitivity to the information provided by external stimuli predicts higher boredom experience and ADHD symptoms in an individual. In mouse subjects, we study the neural representation of information provided by auditory stimuli, finding that the entropy of a given sound stimulus is encoded by the magnitude and pattern of the corresponding evoked neuronal response. Here, a specific set of neurons shows stimulus-independent tuning to entropy, anchoring information content in the representational geometry of the auditory cortex. Together, we highlight boredom as a cognitive response to states of low information, that is reflected by specific neuronal activity patterns and promotes explorative behavior.

**Keywords**: *Boredom, Information, Exploration, Auditory Cortex*

## (33). Affective Framing Influences Information Consumption, Donations, and Memory

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**Abstract:** Negativity captures attention and motivates information seeking and sharing. However, negative messaging can also harm mental health and discourage sustained action to address crises like climate change. One theory of motivation proposes that imperative motivation—associated with threat, urgency, and noradrenergic modulation—drives immediate goal-relevant behavior, but constrains attention and memory. In contrast, *interrogative* motivation—associated with reward, curiosity, future goals, and dopaminergic modulation—promotes information seeking and integrative memory formation. Here, we explored these predictions in the context of news consumption. We adapted climate-related news headlines to emphasize *Crisis* (disaster and urgency; imperative motivation) or *Opportunity* (positive future goals; interrogative motivation). Across two experiments, one preregistered (N=292, N=395), we found that headlines that evoked stronger affect

(positive or negative) increased reading intentions, sharing intentions, and real donations to related charities (all *p*-values < 0.0001). Crisis and Opportunity framing both increased reading and sharing intentions relative to the unaltered headlines (as originally published); the effects of framing were mediated by affect (*p*-values<0.05). Consistent with theoretical predictions, Crisis framing had stronger effects on immediate actions like sharing and donating (*p*-values<0.01), whereas Opportunity framing led to better memory for news content (*p*-values<0.001). Lastly, we computationally classified the affective framing of >25,000 climate related news headlines on social media; stronger positive or negative framing was associated with increased likes and reposts across news outlets (*p*-values<0.0001). Overall, we show that Crisis and Opportunity framing can both motivate information seeking and sharing, but have opposing effects on affect and memory. In ongoing work, we are adapting this paradigm for fMRI to investigate the neural systems that operate at this intersection of information consumption, valuation, and memory. Our findings offer insights for theories of information seeking and motivated behavior, as well as applications for mass communication related to important societal challenges like climate change.

Key words: *information seeking, information sharing, motivation, affect, memory*

## (35). Modelling uncertainty around subjective values of two choice attributes increases analysis sensitivity

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**Abstract:** Self-reported estimates of subjective values (ratings on Likert/continuous scales) are used extensively to test the theories of human decision making, and to define study outcomes (e.g., self-control in food choice). However, rating precision is generally neglected in such studies. We model uncertainty around self-reported subjective values for two choice attributes. In a hypothetical bias-free choice (exclusively driven by attributes *X* and *Y*), we postulate true attribute rating differences that produce a simple rule: assuming no difference in attribute *X*, if item A is rated higher than B on *Y*, item A is chosen. Then, we assume (i) bivariate normal distribution $N(\mu,\Sigma)$ around self-reported attribute rating differences ($\mu$), with its conditional probabilities reflecting this rule, and (ii) whether correlation and standard deviations in $\Sigma$ differ among experimental conditions and the types of choice (with/without intended conflict between attributes (defined using self-reports)). We estimate $\Sigma$ from self-reported attribute ratings and binary choices of many products. Using food choices as an example, we employed $N(\mu,\Sigma)$ to calculate the probabilities of self-control (choosing a healthier and less tasty food item over a less healthy and tastier one) and choice-attribute consistency (choosing a healthier and tastier item over less healthy and less tasty one). We analyzed data from an experiment that tested the effect of increased working memory load on food choices. Irrespective of assumptions in (ii), we found that increased load reduced choice-attribute consistency ($-2.78<z\text{-}score<-2.02$), but not self-control, and that self-reported number of weekly unhealthy snack consumption was negatively associated with self-control in the lab ($-4.72<z$-

*score*<−2.14). Simple binary measures could not detect these two significant results (*p-value*<0.05) nor any other load effects on choices. Our method may be more sensitive in detecting effects of interest compared to binary measures when outcomes are defined from imprecise subjective value ratings rather than the unknown true values.

**Keywords:** *subjective value, two-attribute choice, attribute rating uncertainty, binary food choice, cognitive load.*

### (37). Emotional control predicts changes in decision-making under negative affect

*Sydney Trowbridge*

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**Abstract:** Value based decision-making is known to be affected by emotional states. Different aspects of how individuals experience and handle emotions may affect the extent to which their decision-making is altered by negative emotion.

*Objective:* The aim of this study is to investigate how individual differences in emotional awareness and control moderate changes in risk and ambiguity preferences due to negative affect. *Methods:* Healthy adults completed emotion questionnaires at a baseline visit. In two experimental visits, participants watched a negatively valenced video with fear-, disgust-, or sadness-inducing content or a sham video. Participants then completed a risky decision-making task where they chose between a certain gain/loss of $5 or playing a lottery where they could win/lose a different amount. Lottery reward, probability, and ambiguity level varied trial-by-trial. Following their choice, they rated their confidence on a 1-4 likert scale. Based on a factor analysis of the questionnaires, resulting latent variables of emotional awareness and control for each participant were used in subsequent analyses. We fit a risk and ambiguity utility model to choice data to derive estimates of individuals' risk tolerance, ambiguity tolerance, and choice stochasticity. *Results:* Out of 30 participants who completed the experiment, 17 performed the risky decision-making task immediately after the emotion induction. Negative affect was associated with increased risky lottery choices ($t(16) = 2.15$, $p = 0.047$), particularly in the loss domain, and increased choice stochasticity in the gain domain ($t(16) = -2.31$, $p = 0.028$). We found no effects of negative affect on confidence, and no statistically significant relationships between emotional control and baseline behavior. However, there were significant moderation effects of emotional control when looking at the change in behavior under negative affect. In the gain domain, higher emotional control was significantly related to more willingness to choose the lottery compared to baseline ($r = 0.51$, $p = 0.038$) and increased choice stochasticity ($r = -0.65$, $p = 0.005$). In the loss domain, emotional control was significantly related to a decrease in choice stochasticity ($r = 0.51$, $p = 0.038$). Emotional awareness did not relate to any aspect of changes in behavior. *Conclusion:* Our preliminary results show that negative affect reduces risk aversion and worsens choice stochasticity in gains, while making choices in the loss domain more deterministic. They also suggest a role for individual differences in emotional control in moderating these effects. Future work will test the extent to which this relates to psychopathology.

**Keywords:** *D - Risk & Uncertainty; I - Valuation & Decision Making; J – Emotion*

## (39). At what cost?: Social Value-based Purchase Decisions in Liberals and Conservatives

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**Abstract:** *Objective:* Using an embodied-choice approach and building on previous mouse-tracking literature demonstrating that cursor movements reliably encode the deliberation process, we created a novel mouse-tracking paradigm for purchase decision deliberation. Additionally, we intend to understand if individual differences in political orientation manifest as differences in reach trajectories while participants process the product information. *Methods:* We created a novel, Buy/Don't Buy mouse-tracking paradigm where participants (N = 291) make purchase decisions based on a product's price and the brand's eco-friendly or humane labor rating. Participants are assigned to either Ethics Rating (experimental condition, N = 144) or a Customer Rating, (control condition, N = 147). Price and product rating (either ethics or consumer evaluation) was sequentially revealed as participants moved the mouse from the bottom center of the screen towards the decision targets located on the top corners of the screen. Half the trials presented only price and the other half presented both price and product ratings. *Preliminary Results:* Initial choice analysis demonstrate that within Conservatives, there is no between-subjects main effect of Rating Condition, suggesting their purchase decision did not change based on the product rating type. There is no main effect of, or interaction with, Rating Presence, reflecting that their choices were not impacted by the presence of product ratings. In Liberals, there is a main effect of Rating Condition indicating more items are bought in the Ethics condition; as well as a three-way interaction of Price (expensive vs. inexpensive), Rating Presence and Rating Condition. Based on unpacking of this three-way interaction, we found that in the Ethical condition, more items are picked when the rating appears early and the price appears late, compared to when the price appears first and the ethical rating appears closer to the decision horizon. In the Customer condition, more items are picked when no rating is present, and items are picked more when the price appears closer to the decision horizon. *Conclusions:* This novel task design mimics a real-world decision environment to provide insights into the deliberation process, role of action costs in decision development, and the interaction of price and indictors of social value. Our preliminary results demonstrate significant differences in purchase decisions across conservatives and liberals, indicating underlying differences in deliberation. Future analysis will investigate the mouse movement trajectories to reveal these differences in deliberation process based on their political orientations.

**Keywords:** *B - Consumer Behavior & Marketing; F - Social Behaviour; I - Valuation & Decision Making*

## (43). Inferring subjective arousal from pupil size

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**Abstract:** Although pupillary dilation has long been associated with subjective arousal, researchers have not yet clarified the affective meaning or temporal dynamics of this association within individuals. To examine whether pupil size could predict self-reported

arousal, we recorded pupillometry from 95 participants across three studies (two Virtual Reality Studies and one neuroimaging study) as they completed a modified Monetary Incentive Delay task with self-reported probes of affect either during reward anticipation or reward outcome. Together, tonic and phasic pupil dilation during incentive processing predicted subsequent subjective arousal better than did either signal in isolation (variance explained: 14.1%, 10.5% and 4.3% across three studies), and did so most robustly at an approximate lag of one to two seconds. Pupil size during self-report of affective experience, however, did not correlate with arousal. Functional Magnetic Resonance Imaging confirmed that activity in brain circuits innervated by norepinephrine (e.g., locus coeruleus, thalamus, anterior cingulate, and anterior insula) also correlated with pupil size. Greater neural similarity (calculated as the rank correlation of voxel pattern) to the pupil-derived GLM template positively predicted behavioral indicators of arousal, including whether they could hit the target (std. beta = 0.204, z = 4.485, p < .001), their reaction time when hitting the target (std. beta = -0.061, t = -3.709, p < .001), as well as subsequently self-reported arousal (anticipatory probe: std. beta = 0.135, t = 3.260, p = .001; outcome probe: std. beta = 0.138, t = 3.413, p < .001). This work provides convergent evidence that pupillary dilation in response to incentives predicts self-reported arousal seconds later, underscoring its utility as an indirect measure of the dynamics of a key dimension of affective experience.

**Keywords**: *pupillometry, monetary incentive, affect, self-report, arousal*

## (45). Preschool children's learning and generalization of continuous causal functions

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**Abstract:** Many causal relations can be represented by continuous functions that map inputs to outputs (e.g., when using a dimmer switch, the position of the slider affects the brightness of the light). Can young children learn continuous causal functions and generalize them from observed data to new scenarios? Furthermore, given that positive linear functions are easier to infer than other forms of functions for school-age children (Zhou et al., 2024) and adults (Brehmer, 1974), do young children show a similar inductive bias? Four- and five-year-olds (pre-registered *N* = 48) interacted with machines that played music for different lengths of time when different-sized blocks were placed on them. For each machine, the music duration varied as a function of block size; different machines represented positive linear, negative linear, triangular, and step functions (Figure 1). Children observed the effects of some different-sized blocks on the machine, before predicting the effects of blocks of unobserved sizes (Table 1).

Children's learning accuracy indeed differed across functions (χ2(3) = 49.88, *p* < .001). Specifically, accuracy was above chance (⅓) for the positive linear (*M* = .84, *p* < .001) and step (*M* = .66, *p* < .001) functions, and performance was at chance for the negative linear (*M* = .31, *p* = .79) and triangular (*M* = 0.18, *p* = .051) functions. Children learned the positive linear and step functions more accurately than the other two functions, suggesting a bias towards inferring monotonically increasing functions. While

we did not find an overall age effect (□2(1) = 2.27, $p$ = .13), the effect of age varied across functions (□2(3) = 10.34, $p$ = .016). Age only improved performance on the negative linear function ($z$ = 3.24, $p$ = .001) but not the others (all $|z| \leq 1.59$, all $p > .11$), as understanding the former might have required fully inhibiting the possible positive linearity bias.

**Keywords:** *causal learning, function learning, development*

Figure 1. Four different forms of functions (observed data are in red).

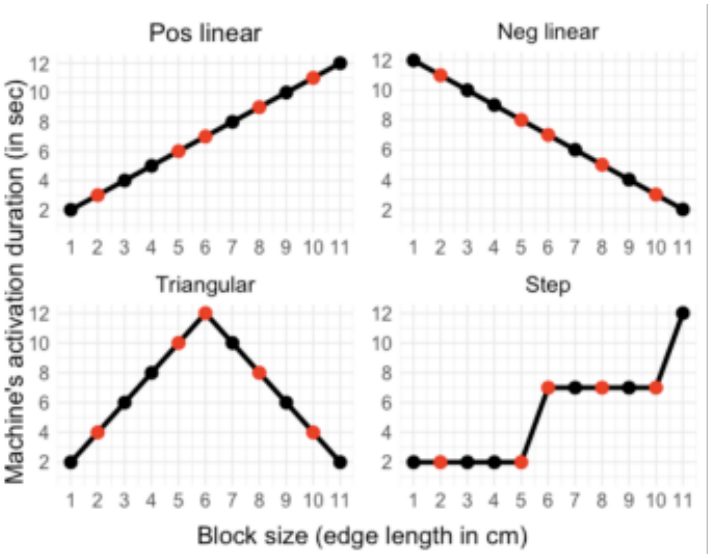


Table 1. Prediction questions and correct answers by function.

| *"Will **[Block A]** make the machine go for longer, will **[Block B]** make the machine go for longer, or will they make it go for the **same** amount of time?"* | | | | |
|---|---|---|---|---|
| | **1 vs 2** | **3 vs 9** | **7 vs 9** | **1 vs 11** |
| **Pos linear** | 2 | 9 | 9 | 11 |
| **Neg linear** | 1 | 3 | 7 | 1 |
| **Triangular** | 2 | Same | 7 | Same |
| **Step** | Same | 9 | Same | 11 |

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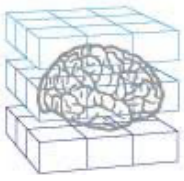

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