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Oral Presentation Abstracts

Friday October 5, 2018

Session I Intertemporal Decision Making and Self Control

Neural and behavioral correlates of long-term memory are associated with temporal discounting in older adults

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Most people show temporal discounting (they prefer immediate to delayed rewards), but the rate at which people discount future rewards varies widely. What are the neural mechanisms that underlie individual differences in temporal discounting? Two candidate neural systems have been implicated in previous fMRI studies. One, primarily involved in executive function, is localized to prefrontal cortex. The other is involved in long-term memory and prospection and depends on the temporal lobe. Both systems decline as people age, at variable rates. Here we leverage this variability among older adults to examine the association between frontal and temporal lobe-mediated processes and temporal discounting. We also tested whether discount rate was associated with a neural measure of cognitive decline, white matter hyperintensity (WMH) volume. These white matter lesions (detectable as areas of hyperintense signal in white matter on FLAIR MRI) are common in older adults. They are associated with decreased cortical thickness in frontal and temporal regions, and they predict global cognitive impairment. 100 older adults (ages 58-94; 76 cognitively normal; 24 with mild cognitive impairment, MCI) completed a neuropsychological test battery, an intertemporal choice task, and a risk task. Risk aversion parameters were used to estimate utility before fitting a hyperbolic model to estimate discount rate. Participants with better long-term memory (i.e., a higher composite delayed recall score) discounted delayed rewards less, even when controlling for age, gender, race, and education (β=-0.48; p=0.005). Executive function, assessed with the Trail Making Test, was not correlated with discounting (β=-0.12; p=0.76). The discrepancy between semantic and lexical fluency, a measure of temporal lobe function that controls for frontal involvement, also predicted discount rate (β=-0.55; p=0.005). Overall WMH burden (available for N=71, N=15 MCI) was positively associated with discounting, controlling for intracranial volume, age and gender (β=0.55; p=0.008). Highlighting the specificity of these results, there was no relationship between memory recall and risk aversion (r=0.03; p=0.76), or WMH burden and risk aversion (β=0.01; p=0.925). Long-term memory ability, but not executive function, is associated with temporal discounting in older adults. We also find a novel relationship between white matter lesions and discounting. These results suggest that discount rates may increase as long-term memory declines with aging. It is possible that connections between temporal regions and frontal valuation regions, which may be impaired by white matter lesions, are integral to patient choice.

Monetizing the subjective cost of self-control

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Decades of research have attempted to understand why individuals choose tempting rewards that do not align with their overall goals, a class of choices often referred to as 'self-control failures'. To account for these choices, emerging work has sought evidence that self-control imposes real costs that could be measured. These value-based frameworks suggest that deviations from stated goal-directed behavior may arise from a rational decision-making process that weighs the costs and benefits of exerting cognitively demanding control. Such rational economic models of shifting behavioral goals posit that choosers always aim to maximize expected utility, but that apparent failures are evidence of shifting underlying costs, extending these cost-benefit principles to the mobilization of self-control. If self-control is indeed costly, an important strategy to avoid deviations from goal-directed behavior might be to prospectively eliminate or restrict temptation from one's environment--known in behavioral economics as 'pre-commitment'. In economic terms, this is a form of rational menu reduction designed to limit costs due to self-control exertion (Gul and Pesendorfer, 2001). Here, we developed and tested a novel economic decision-making task aimed at measuring the costs individuals were willing to incur in order to use pre-commitment to avoid temptation, allowing us to directly measure the cost of exercising self-control. In our study, healthy, hungry dieters first provided health, taste and temptation ratings for food items, allowing us to identify a highly tempting food for each individual. Both before food exposure and at regular intervals after exposure, participants reported their willingness-to-pay to remove this tempting food for the remainder of the experimental period, effectively revealing their subjective cost of exercising control. Bids were realized using a standard economic auction procedure (Becker-DeGroot-Marschak method) at a fixed low hazard rate. We found that individuals were willing to pay approximately 30% of their endowment to avoid temptation, confirming that self-control is indeed perceived to be costly to choosers. We replicated these findings in a second independent cohort of dieters. Consistent with an emerging framework viewing goal-directed control as a cost-benefit decision process, these data suggests that idiosyncratic self-control costs can be objectively quantified in humans and that these costs conform to the rational choice model of self-control proposed by Gul and Pesendorfer. These findings may open new avenues of research investigating how reducing self-control costs can promote more adaptive decision-making.

Dietary self-control depends on the latency and rate of information accumulation during choice

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The drift diffusion model (DDM) provides a parsimonious explanation for decisions across neurobiological, psychological, and behavioral levels of analysis. This model posits that evidence in favor of each option is accumulated over time. Once a threshold is reached for one option, a decision is made. To date, most DDM applications have assumed the value accumulation process is influenced by only one type of information, such as the quality of a signal in perceptual tasks, guides choices. However, many real-world choices faced by consumers involve integration across multiple types of information that collectively determine the value of an option. If these different attributes are processed and weighted differently, models using overall value may be unnecessarily limited in their explanatory power. Here, we propose a multi-attribute, time-dependent, drift diffusion model (mtDDM) that allows two different attributes to influence choice independently. We apply the mtDDM to empirical data from an incentive-compatible dietary choice task and show that two attributes - taste and health - have distinctly different influences on the decision process and predict different components of individual variance in dietary

choice. The ability to make healthy choices, often thought to be controlled by the capacity to exert willpower, is largely determined by two mtDDM parameters, one of which may be unrelated to self-control. Our results indicate that taste information has two advantages during the decision process - first, it contributes relatively more to evidence accumulation, and second, it is processed earlier than health, allowing it to contribute evidence for relatively longer. For most individuals in our sample, health information enters the decision process too late, relative to taste, to drive choices toward the healthier option, regardless of the underlying weight placed on health during evidence accumulations. Further, using a dietary nudge, we successfully shift both behavior and parameters of the mtDDM. These results indicate that distinguishing the influences of different attributes not only improves laboratory models of dietary choice but also provides directions for new consumer interventions.

Insights into the neural and behavioural impacts of WM training in school-aged children

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Aim: Previous work indicates that there is an association between working memory (WM) performance, attention, and impulsive behaviours. Cognitive training programs for children may enhance the maturation of fronto-parietal networks underlying the age-related increase in cognitive control control (Crone et al 2006) however, their impact on the cognitive and academic dimensions have yet to be investigated. We conducted an fMRI study to investigate the neural and behavioural impact of a school-based WM training intervention on attention and inhibition. Methods: We collected behavioural and fMRI data on a subset (n =28, 14 with WM training) of a sample of 500 typically developing 7-8 year-old children who underwent WM a control training in a classroom setting. Our subset performed working memory, attention, and intertemporal choice tasks while in the fMRI scanner. Results: Performance on both the WM and attention tasks was better in the WM training group compared to the controls (WM task: commission errors load x treatment interaction effect: $F(1,23)= 5.621$, $p=0.027$, coefficient of variation WM load effect $F(1,23)=10.046$, $p=0.004$, treatment effect $F(1,23)=5.359$, $p=0.03$; attention task: d-prime trial type effect $F(1,22)=16.488$ $p=0.001$, treatment effect $F(1,22)=5.681$ $p= 0.026$, coefficient of variation trial type x treatment interaction effect $F(1,22)=5.955$, $p= 0.023$). In addition, although discount rates did not differ, DDM-derived drift rates were higher in both the attention and choice tasks for WM compared to control participants. The one-year follow up showed that better performance on the attention task and on the WM task immediately after the training was associated with higher scores on well-being screening measures (Strength and Difficulties Questionnaire Total Score), and lower scores on impulsivity measures (number of Go-NoGo commission errors), respectively. The fMRI data showed that group differences in performance were accompanied by significantly increased activation in a network of regions typically recruited during WM, attention and inhibition processes including putamen, dlPFC, IFC/insula and anterior cingulate cortex. Conclusion: Our results suggest a potential mechanism of action for the significant impacts of the WM training on behaviour and neural networks. These impacts appear to be strongest for attention and inhibition processes, considered as pre-requisite skills for working memory as well as many other high-level cognitive processes, which may play therefore a mediating role on the observed training effects.

Saturday October 6, 2018

Session II Valuation and Choice

Time and frequency dynamics of directed attention in stimulus attribute weighting

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Objectives: There is a growing consensus that we make decisions by differentially weighting stimulus attributes relevant to choice, a process attributed to the ventromedial prefrontal cortex (VMPFC). Although attribute weighting is thought to rely on attention, particularly during self-control, the neural mechanisms underlying this process remain unclear. Here we investigated two possible mechanisms by which attention could influence attribute weighting: top-down orienting via fronto-posterior networks versus late modulation of VMPFC value signals. Based on previous data, we hypothesized that orienting would be associated with low-frequency oscillations in the alpha band (8-14 Hz) roughly 100-150 ms after stimulus onset, whereas later attentional selection for health attributes would be associated with synchronous high-frequency gamma-band activity (40-100 Hz) within frontal sensors approximately 550-650 ms post-stimulus onset. Methods: We measured event-related potentials (ERP) while hungry participants made dietary choices in three attentional cueing conditions: responding naturally, focusing on taste, or focusing on health. Participants were explicitly instructed to respond freely based on their preferences regardless of the attentional cue. Results: Behaviorally, participants demonstrated significant shifts in attribute weighting in line with the cues. Consistent with top-down orienting, neural activity correlated with healthfulness ratings showed significant increases in alpha power for health versus taste cueing conditions at frontal and occipital sensors from 100 to 150 ms post-stimulus onset. In contrast, ERP correlates of attentional cueing emerged at central sensors from 550 to 700 ms after stimulus onset, overlapping in time with value signals localized to VMPFC. However, neural activity also differed significantly by cue condition, as indicated by significant interactions between attentional cue and decision value. Value signals showed the greatest amplitudes and strongest linear ordering in the health cue condition, corresponding to an increased weighting on healthfulness, and the strength of this increase correlated with individual differences in the behavioral weighting of health. Time-frequency analysis of the neural response to health attributes in this time period revealed significant increases in gamma power during health versus taste cueing, concentrated predominantly at frontal sensors. Conclusions: Together, these data provide further support for the role of attention in attribute weighting, while elucidating how this process reflects dynamic synchronization of neural populations across multiple time windows and frequency bands.

Assessing consumer demand in a random utility model with noisy neural measurements

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A number of recent studies have used the random utility framework to examine whether neural data can assess and predict demand for consumer products (Knutson et al., 2007; Tusche et al., 2010; Gross et al., 2014; Smith et al., 2014; Telpaz et al., 2015). In particular, activity in the ventral Striatum (vSTR) seems to have robust out-of-sample predictive ability, even at the market level (Venkatraman et al., 2015; Genevsky et al., 2017). However the effectiveness of this methodology has been limited by the large degree of measurement error in neural data. This "error-in-variables" problem severely biases the estimates of the relationship between neural measurements and choice behaviour, thus limits the role

such data can play in assessing marginal contributions to utility. Previously reported estimates of this relationship are all too small, yielding an increase in Type II errors and overly conservative prediction rates. In this article, we propose a novel method for controlling for the large degree of measurement error in value signals from mPFC and vSTR. We propose that additional neural measurements can serve as "proxies" for the measurement error in these value regions, substantially alleviating the bias in model estimates. We provide two conditions for the existence of such proxy variables: 1) they must not, by themselves, predict choice behaviour, and 2) they must be correlated with signals from mPFC and vSTR. Both of these conditions can be easily tested using standard statistical tests. We demonstrate the feasibility of our proposed method on an existing dataset of fMRI measurements and consumer choices (Levy et al., 2011). We consider two candidate control regions, BOLD activity from the Occipital Cortex and the posterior Insula, and include these observations in the estimation of a neural random utility model via Maximum Simulated Likelihood. We find a substantial increase (~50%), in the estimated relationship of both mPFC and vSTR to choice behaviour and find a marked improvement in out-of-sample predictive performance (+15% for the highest valued items). We also find a substantial decrease in the variance across subjects, suggesting that much of the heterogeneity typical in such studies is due to heterogeneity in measurement error. In fact, for the vSTR, we cannot reject the hypothesis that a unit increase of neural activity in one subject yields the same change in choice probability as a unit increase in another subject ($p>0.08$).

Prefrontal projections to striatum persistently encode decision variables

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In dynamic environments, the brain relies on recent experience to make adaptive decisions. Despite the ubiquity of this phenomenon, the neural mechanisms of flexible decision making are poorly understood. Here, we identified how the medial prefrontal cortex (mPFC) persistently encodes value-based decision variables to generate flexible behavior. We developed a dynamic foraging task in head-restrained mice, adapted from one in monkeys (Sugrue, Corrado, Newsome, 2004; Lau, Glimcher, 2005; Tsutsui, Grabenhorst, Kobayashi, Schultz, 2016). Mice chose between two lick ports, each of which delivered reward with probabilities that changed over time. To obtain a generative understanding of behavior, we developed a simple action-value reinforcement-learning model which predicts that animals produce dynamic values for each action. We demonstrate that the relative value (difference between the two action values) predicted choice behavior and that the total value (sum of the two action values) predicted choice reaction time. To determine how mPFC contributes to behavior, we reversibly inactivated it. This prevented mice from updating actions adaptively and increased reaction times, demonstrating the necessity of mPFC for flexible decision making. Experiments using other behavioral tasks revealed this effect was not due to a deficit in mapping decisions onto motor outputs (i.e., licking appropriately in either direction), nor was it due to slowing of movements. We next recorded action potentials from >3,000 neurons in ten mice performing the foraging task. We discovered highly dynamic persistent firing rates in the majority of neurons that lasted for tens of seconds or longer. One population of these neurons dynamically encoded relative value, a control signal necessary for decision making. Another population of neurons encoded total value, predicting reaction times. Many neurons jointly encoded relative and total value. To test whether these persistent representations may inform action selection, we recorded action potentials from mPFC neurons projecting to dorsomedial striatum. We discovered that mPFC projections to striatum persistently represented relative value and total value. Thus, we define a specific mechanism for mPFC to drive flexible decision making.

Evidence for past and present subjective value signals in the human orbitofrontal cortex

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There is accumulating evidence suggesting that the orbitofrontal cortex (OFC) represents the subjective value (SV) of options essential for value-based decision-making. A growing body of research further indicates that value representations in OFC are sensitive to both past and present rewards and that OFC encodes relative SV that depends on temporal context of experience. However, these findings are predominantly based on single-unit electrophysiology in non-human primates and have not been widely reported in humans. In this study, we investigated value representations in the human OFC using intracranial electrophysiology (stereo-electroencephalography, SEEG). Four subjects implanted with multi-contact depth electrodes performed a Becker-DeGroot-Marschack (BDM) auction task on snack food items to elicit and estimate the subjective value (SV) of rewards. Two 2500-ms time windows were extracted from the SEEG data: one time-locked to the stimulus onset, the other time-locked to the response onset. The high gamma power (80-150 Hz) - previously shown to positively correlate with the firing rate of single neurons - was extracted. For each SEEG contact on each subject, we regressed 50-ms time-binned high-gamma power against the SV of the present reward and of the reward in the previous trial. A contact was considered value-related if the regression coefficient is significant ($p < 0.05$) for three consecutive 50-ms time bins. All four subjects showed value-related representations in the OFC: three subjects showed significant representation of current SV and three showed significant representation of previous SV. Two out of four subjects showed both current and previous SV representations in the same time windows (stimulus-locked and response-locked). Interestingly, both subjects had contacts that showed opposite signs of correlation with previous and current SV, suggesting subtraction-based relative SV computations. In summary, using human SEEG, we found evidence that high-gamma activity in the human OFC encodes current as well as previous SV for food rewards. Furthermore, our results provide support to the hypothesis that OFC computes relative value that is sensitive to the temporal context of experience.

Session III Learning and Memory

The effect of counterfactual information on outcome value signal encoding: Evidence for fully-adaptive coding along the rostrocaudal axis of the medial prefrontal cortex

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OBJECTIVE When we make a decision, usually we experience its consequences but we have no information about potential outcomes of alternative decisions we could have made. Yet, this additional information is useful to improve learning (e.g., Palminteri et al., 2015). In this study, we analyzed brain activity related to outcome processing in loss and gain contexts to explore the neural coding of value for both factual and counterfactual outcomes, when either partial or complete feedback about the outcomes is provided. The aim of the experiment is two-fold: 1) to investigate where factual and counterfactual information is represented and 2) to unravel how outcome value is encoded in different feedback conditions. We hypothesize that counterfactual information will produce rescaling of value

signal depending on the context, such that the value of a neutral outcome becomes positive in a loss context (as absence of punishment) and negative in a gain context (as absence of reward), thus reflecting fully-adaptive coding of value signals. METHODS Twenty-eight participants performed a probabilistic instrumental learning task while undergoing functional magnetic resonance imaging scanning. On each trial, they had to choose between two symbols probabilistically associated with a certain reward (or punishment). Then, the outcome of the decision was revealed. Importantly, on half of the trials participants received feedback only about the outcome of their decision (partial feedback condition), while in the other half they were informed about both the factual and the counterfactual outcome (complete feedback condition). We used univariate analysis as well as multivariate pattern classification (Haynes, 2015) to explore outcome value processing and encoding of factual and counterfactual outcomes, in trials with either complete or partial feedback. Furthermore, we assessed neural coding of outcome value in these two conditions. RESULTS Our results show that: 1) not only factual but also counterfactual information can be decoded from local patterns of brain activity, 2) brain activation in regions along the rostrocaudal axis of the medial prefrontal cortex (mPFC) increases for processing of factual outcomes but decreases for counterfactual information processing, 3) outcome decoding is significant in less rostral regions of mPFC, and 4) outcome value is represented with a fully-adaptive code when complete feedback is provided, while it is encoded in an absolute way when feedback is partial. CONCLUSION These findings suggest that outcome value processing is implemented through multiple coding mechanisms flexibly activated depending on the specific choice setting at hand.

Modeling structure in learning to self-regulate motivation via veridical real-time fMRI neurofeedback from the ventral tegmental area

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INTRODUCTION: The ventral tegmental area (VTA) and its dopaminergic projections are central to volitional behavior. Previous work from our group demonstrated that individuals can learn to self-activate the VTA using self-generated motivational imagery during real-time neurofeedback training, but only with veridical VTA feedback. Here, we investigate how the temporal structure of neurofeedback training predicts transfer. METHODS: Using a previously detailed task (MacInnes et al., 2016), participants learned to volitionally upregulate VTA response. Briefly, participants completed a pre-test, 3 training runs, and a post-test. During training, they received real-time fMRI neurofeedback from the VTA (N=19) via a graphical thermometer every 1 s over a total of 15 20-s trials (3 per run). Another group (N=14) received Gaussian noise instead of veridical VTA feedback. All participants received minimal instruction about how to self-activate and their strategies were not reported until after the scan. Thus, our analyses were blind to the strategies used, instead focusing on the effect of context. To examine the structure of neurofeedback learning, we used MATLAB (v2016b), first extracting mean VTA response during training (ie, the feedback signal) at the single-participant level; we then resampled the signal to 2 Hz and rescaled it to [-1,1]. Next, we computed the slope of the feedback time series in three temporal contexts: single trial, scanner run, and full training session. This produced parameters reflecting learning during each context (trial: 15, run: 3, session: 1). We then used linear regression to examine how well these parameters predicted transfer, indicated by the change in average VTA response from pre- to post-test, fitting one model per temporal context on the group-level. Finally, we estimated and compared model evidence. RESULTS: The slope of VTA activation change over the entire course of training predicted the magnitude of transfer (adj. $R^2=0.335$, $F_{2,17}=8.56$, $p<0.01$). An initial comparison of model evidence suggested that the full session was the best model for the data (AICc: -2.58, BIC: -1.44) relative to other contexts (AICc, BIC; trial: 243, -13.9 and run: 10.8, 11.7). Further, only the full session explained

group differences in transfer, showing a trend toward more negative slopes under noise feedback (p=0.053). CONCLUSIONS: These data suggest that, regardless of strategy, successful learning from VTA neurofeedback is most linked to the training context as a whole, with this longer-term trend also explaining feedback group differences. Future work will further characterize relative contributions of the different contexts to learning.

The role of dopaminergic midbrain nuclei in predicting monetary gains and losses: Who's doing what?

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The ability to correctly predict the outcomes of actions based on previously experienced gains and losses is crucial for our survival and success in a constantly changing environment. Animal studies using invasive electrophysiological methods have found reward-related activity in dopaminergic nuclei in the midbrain, supporting learning about actions and their consequences in a reinforcement learning framework. However, human studies using non-invasive neuroimaging methods have almost exclusively investigated neuronal activity in the target areas of these nuclei. Due to their location deep in the brain, their chemical composition, and their small size, midbrain nuclei are difficult to study with common neuroimaging tools. By using a state-of-the-art scanner (ultra-high-field 7 Tesla MRI), as well as structural and functional scanning protocols specifically tailored to iron-rich midbrain nuclei, the present study aims to solve some of the ongoing debates in the literature: Which midbrain nuclei are responsible for the prediction of monetary gains as opposed to losses? And which nuclei update these predictions when realized gains or losses are more or less than expected? To obtain high anatomical specificity, we invited participants in two separate sessions: one to obtain high resolution anatomical images in different modalities, and one to obtain functional data during a gambling task. Based on the anatomical images, we could delineate individual masks for two dopaminergic nuclei - substantial nigra (SN) and ventral tegmental area (VTA) - and therefore extract activity from these masks to perform anatomically precise region-of-interest analyses. Our results show a significant risk signal in the left VTA and left SN, a significant reward prediction error (RPE) signal in bilateral VTA and in the right SN, and a surprise signal in the right SN. Because a surprise signal was found significant in SN, activity in this area falsified the axiomatic RPE model (Caplin & Dean, 2008), suggesting a role that has more to do with saliency of an outcome for SN. Finally, we found a significant overlap between our individual VTA masks and previously proposed SN masks in the MNI space. In the light of these results, we stress the importance of not only using ultra-high field MRI to probe neuronal activity of small dopaminergic nuclei in the human brain, but also the importance of drawing individual masks for these nuclei in order to obtain sufficient anatomical precision for separating signals from adjacent midbrain nuclei, such as VTA and SN.

Sunday October 7, 2018

Session IV Social Rewards and Social Preferences

Decoding proposers? Motivations in the ultimatum game from multivariate brain activity patterns

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In the Ultimatum Game (UG), the proposer may have different motivations for splitting their endowment evenly. They may do so out of fairness concerns or because they want to avoid rejection of the offer on the responders' side. Here, we used fMRI to identify neural patterns that discriminate between these two motivations. Participants played twelve rounds of the UG and Dictator Game (DG), involving real money, as proposers. Due to the fact that responders cannot reject the offer in the DG, the offer size as well as the neural mechanisms underlying decision-making between these two games should differ for fairness driven versus strategic decision makers. In contrast to fairness concerned proposers, strategic proposers are assumed to offer considerably less money and are assumed to recruit different neural processes in the DG as compared to the UG. We used support vector classifiers trained on whole brain activation patterns to classify which game the participants were playing. Secondly a classification searchlight was employed to explore where in the brain we can decode which game was played. Lastly, a representational similarity analysis (RSA) searchlight procedure was used to investigate where in the brain the neural similarity between games correlated with individual differences in offer size between games.Results indicated that we were able to accurately discriminate between neural patterns associated with UG and DG trials. More importantly, we found that the classification accuracy for the participants correlated strongly with their average difference in offer size between UG and DG, indicating that higher difference in offers is associated with greater differences in neural activity across games. The classification searchlight revealed that we could accurately decode game type in the inferior frontal gyrus (IFG), the orbitofrontal cortex (OFC), insula and anterior cingulate cortex (ACC). Lastly, we found that dissimilarity between neural patterns associated with the two games correlated significantly with individual differences in offer size between games in the amygdala, posterior cingulate cortex (PCC) and the middle frontal gyrus (MFG). Thus, these regions contain information about individual differences in motivations. Our results provide insights into the underlying neural mechanisms of social decision-making as patterns of brain activity are identified that discriminate between players' underlying motivations for their economic decisions.

How positive and negative role models drive plasticity in moral preferences

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Objective: Moral preferences are susceptible to influence from positive and negative role models. However, it remains unknown whether positive and negative influence operate via similar or different cognitive mechanisms, and how individual differences in moral preferences affect susceptibility to influence. Methods: We deployed a multi-stage paradigm to probe the computational bases of moral decision-making and moral inference. In an initial decision stage, participants made a series of choices where they traded off profits for themselves against pain for an anonymous stranger. In a second inference stage, participants were randomly assigned to predict either a positive or negative role model's choices on the same task, where the positive role model made substantially more altruistic choices than

the negative role model. In a final decision stage, participants faced the same decision task as in the first stage. We used a drift-diffusion model (DDM) to decompose how much moral decisions were guided by benefits to oneself vs. harm to others. We hypothesized that positive and negative role models would influence moral preferences by increasing sensitivity to harming others and to selfish benefits, respectively. We further predicted these influence effects would be amplified for participants whose initial preferences were more similar to the assigned role models. Results: Participants rapidly learned the preferences of the role models and perceived the positive role model as substantially more moral than the negative role model. Across time, participants' decisions became more similar to the role models whose choices they had predicted. Positive and negative role models influenced moral preferences to a similar extent across participants, but DDM analyses showed that these effects operated via different cognitive mechanisms. Observing a positive role model increased the sensitivity of choices to harm, while observing a negative role model increased the sensitivity of choices to profit. Moreover, the extent of influence was strongest for participants whose own preferences were most similar to the role models. Conclusions: Positive and negative influence had equally strong effects on preferences but operated via different mechanisms: positive influence was characterized by stronger contributions of others' welfare to value accumulation in choice, while negative influence was characterized by stronger contributions of selfish outcomes to value accumulation. Similarity between oneself and the role model amplified these influence effects. Our findings have implications for bolstering and blocking the effects of positive and negative influence on moral behavior

Computational phenotyping in Borderline Personality Disorder using a role-based social hierarchy probe

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Dysfunction in social interactions is a hallmark feature of several psychiatric disorders. However, due to their complexity, social interactions are also extremely hard to study. Experimental economic games have been successfully used to quantitatively analyze behaviors and motives relevant to social interactions, and the emerging field of computational psychiatry has been applying these techniques to understand apparent aberrant social decision-making in people with psychiatric disorders. One important aspect of social interactions that has scantly been studied with experimental economic games is how much people value being in a more dominant social hierarchy role. A mal-adaptive reaction to social dominance may present a significant source of vulnerability for neuropsychiatric disorders, and can be particularly relevant for personality disorders that have trouble sustaining social relations, such as borderline personality disorder (BPD). Here, we were interested in knowing how people with BPD value and behave in social interactions when there are differences in social dominance, and how (or if) these differ from controls. For this, we had participants (169 controls and 312 BPDs) play a multi-round Social Hierarchy game where money could be used to increase (or maintain) social status and applied computational models to the obtained behaviour. We found no difference between BPDs and Controls in the amount of money spent to become (or remain) in the dominant position, the challenge rate, or the number of rounds in the dominant position. However, we found that BPDs in the dominant position transferred more money to the other player. In the computational model, this was associated with a higher inequity aversion parameter, with BPDs showing a higher negative utility from having more than the other when playing against a "nice" computer opponent. Our results suggest that BPDs and Controls value social dominance similarly but that BPDs, when in control, can be especially prosocial, and offer specific computational parameters that can be used to quantitatively characterize and phenotype each individual.

Two heads are better than one: Individuals's future liking preferences predicted jointly by their neural reward responses to--and from--each other

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Why do we end up gravitating to some group members more than others? Can we predict how individuals' initial liking preferences will change over time and whether they will become reciprocated? Social scientists have long pursued better models for predicting individuals' idiosyncratic liking preferences as well as forecasting new acquaintances' future relationship potential.In the burgeoning field of neuroeconomics, numerous studies have found that neural reward responses to various target objects (e.g., consumer packaged goods, cars, etc.) presented as images during an fMRI scan predict participants' preferences among these products. Here we dyadically extended this neuroeconomic paradigm to study the neural underpinnings of interpersonal liking and social ties. That is, we tested whether newly acquainted group members' reward-related neural responses to images of one another's faces could be used to predict who they ultimately end up liking. The study population consisted of an interacting group of 16 young adults involved in an intense summer of labor organizing. At the beginning of the program (T1), they viewed faces of every other social network member while fMRI data were collected (of specific interest, activation of reward system regions-of-interest in vmPFC and VS which were independently defined). Real-world social network members were thus implicated as both the sources and targets of interpersonal neural valuations. We hypothesized that these implicit neural valuations could be used to prospectively predict relational liking sentiments--that is, specific actors' unique attractions to particular partners--measured months later (T2). We found that one's own future (T2) liking of a particular group member was predicted jointly by actor's initial (T1) neural valuation of partner and by that partner's initial (T1) neural valuation of actor. Moreover, these implicit measures of reward-related neural activity mutually predict both dyad members' future liking above and beyond the predictive effects of explicit measures collected at the same time (i.e., both actor's and partner's initial self-reported liking of each other) as well as sociological antecedents of liking. Behavioral findings indicated that liking was initially unreciprocated at T1 yet became strongly reciprocated by T2. The emergence of affective reciprocity was predicted based on the reciprocal pathways linking dyad members' T1 neural data both to their own and to each other's T2 liking outcomes. In this critical way social preferences are unlike other non-social types of preferences, that is, because they are interdependently shaped by our own brains as well as others'.

Session V Choice Models and Mechanisms

Asymmetric overlap in neuronal sensation constrains rational choice in C. elegans

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Rational choice theory in economics assumes optimality in decision-making. One of the basic axioms of economic rationality is "Independence of Irrelevant Alternatives" (IIA), according to which a preference ratio between two options should be unaffected by introducing additional alternatives to the choice set. Violations of IIA have been demonstrated in both humans and in various animals, and could therefore stem from common neuronal constraints. We used the nematode Caenorhabditis elegans, an animal with only 302 neurons and a fully mapped connectome, and developed tests for IIA violations by characterizing C. elegans choices in olfactory chemotaxis assays. In each assay, we exposed the worm to

different odors that activate specific neurons, thus involving in the choice process only defined neuronal networks, and tested whether particular neuronal architectures are prone to producing irrational choices. We found that C. elegans are generally capable of maintaining robust binary olfactory preferences irrespective of the presence of a third attractive odor. However, in very specific olfactory contexts which we term asymmetric overlaps, the preference ratio between two odors varies with the value of a third inferior odor, in a manner that violates IIA and can be considered "irrational" based on the economic definition of rationality. Furthermore, both rational choices and IIA violations in the observed behavior can be explained by a novel computational model of chemosensory decision making. This model employs divisive normalization, a computation widely found in sensory representation and value coding, suggesting that common information processing principles guide choice behavior across different species. Our results show that different network configurations vary in their propensity to give rise to inconsistent decision making. Thus, non-optimal choices could result from simple attributes of neuronal specificity, circuit activation, and constrained computational mechanisms.

A causal account of the brain network mechanisms underlying value-based choices

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Objective: Preference-based choices (i.e., what we should [not] eat) are essential for survival. Recent studies using EEG and transcranial alternating current stimulation (tACS) show that the preference-consistency of such choices is reduced during disruption of gamma-band phase-coupling between frontal and parietal cortex (Polania et al., 2014, 2015). However, the brain network mechanisms that underlie such tACS-induced effects on choice consistency remain unknown. Here we use concurrent tACS-fMRI to investigate these mechanisms. We focus on brain areas related to reward (O'Doherty et al., 2017) and memory (Shadlen and Shoamy, 2016), which we hypothesized might connect with fronto-parietal areas during the readout of values for choice. Methods: Twenty-eight participants took value-based choices during concurrent tACS-fMRI. On every trial, two food items were displayed and the participants had to choose the item they would prefer to eat (one of these choices was implemented after the experiment). In a within-subject design, we compared the preference-consistency of the choices (determined with value ratings acquired before the scan) between a neurally-ineffective sham stimulation and a tACS protocol designed to exogenously decouple fronto-parietal gamma-band synchronization. Neural effects were modeled with a GLM that incorporated regressors for sham and tACS, respectively, as well as parametric regressors for each trial's choice evidence (difference in subjective values) and overall value (sum of subjective values). Results: Compared to sham tACS, participants made more preference-inconsistent choices during tACS. TACS decreased the strength of subjective-value representations in hippocampus and ventral striatum (VS). We tested whether these regions also showed a tACS-induced reduction in value-related connectivity with the two stimulated areas that could account for behavioral tACS effects. Interestingly, the tACS-induced change in behavioral choice stability indeed correlated with the tACS-related connectivity decrease between hippocampus and parietal cortex and between VS and orbito-frontal cortex. Conclusions: The present study reveals brain-network mechanisms underlying decreased value-based choice consistency caused by decoupling the fronto-parietal synchronization. TACS disrupted neural value representations in the memory-value network and reduced connectivity of these regions with stimulated fronto-parietal areas, in a manner that correlated with the strength of the behavioral tACS effects. Our results demonstrate that consistent value-based choices rely causally on interplay between fronto-parietal, reward and memory networks.

The space of decision models

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One of the main goals of scholars of decision making across disciplines is to describe and predict choice behavior. This goal is often accomplished with the use of mathematical and computational decision models. At the most fundamental level, these models specify functions that take as inputs the set of choice options available to the decision maker, and produce as outputs deterministic or probabilistic predictions of choice. Due to the growing popularity of behavioral decision research, behavioral economics, and neuroeconomics, there is now a profusion of decision models. Inevitably, when there are so many models using a few inputs to predict a few behaviors, the models are likely to overlap in terms of their predictions and their key properties. Moreover, this overlap is sometimes unknown to their proponents, who come from different disciplines or different research generations. Here, we provide a synthesis of over 80 different models of simple risky choice and simple intertemporal choice, in a large-scale computational study. Our analysis involves three key steps: (1) A list of choice questions is randomly generated from a reasonable continuous stimulus space; (2) A model, with a random sample of parameters from a reasonable prior distribution, is applied to the set of choice questions to obtain a list of predicted choice probabilities. (3) Another model is fitted to these predicted probabilities to minimize the Kullback-Leibler (KL) divergence between the fitted predictions and the generated predictions. We repeat these steps for all pairwise combinations of models to generate average KL divergences for the entire model space. This metric measures the (asymmetric) similarity of the decision models, and yields a directed weighted graph specifying the structure of the space of decision models. We analyse the resulting graph and uncover model cliques, communities, and hierarchies. Our analysis provides a quantitative specification of how different decision models relate to each other, and sheds light on the different ways in which decision making can be formally studied. With the use of our model space, we are also able to track the main avenues of theoretical development in decision making research across economics, psychology, and neuroscience.

Session VI Complex Decision-Making

Model-based decision making is associated with structure inference ability

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Objective: While recent studies have explored the mechanisms driving model-free and model-based learning, relatively little is known about the individual differences that contribute to one's ability to engage in model-based reasoning. Given that engaging in model-based decision making relies on utilizing learned information about state transitions in one's environment, it is possible that model-based decision-making ability is partly determined by one's ability to infer the structure of those environments on the basis of one or a few disjoint experiences. Here we test the hypothesis that differences in structure inference ability drive individual differences in deployment of model-based strategies. Methods: Participants (N=79) performed a novel task designed to assess structure inference ability. They viewed a sequence of object pairs, each of which represented a pair of adjacent nodes drawn at random from an underlying graph. We then assessed their ability to generalize from these pairs to the graph structure by (a) having them perform a binary choice task requiring an evaluation of the relative distance between sets of three nodes and (b) having them construct the graph. We assessed structure learning using the speed and accuracy of binary choice responses, and also by comparing the relative distances between the nodes on the constructed graph to the true underlying graph. Prior to performing this task,

participants performed a version of Daw et al.'s (2011) two-step task, to assess model-based decision making. Results: Participants were overall able to construct the underlying graph and to use their knowledge of the graph to speed their binary choice responses when the relative node distances were more disparate. Importantly, participants also varied in their ability to infer the structure of the graph, and this variability selectively correlated with how model-based they were on the two-step task (and not with any other performance indices from that task). Conclusion: We show that people who are better able to rapidly infer the structure of an environment - based on individual, disjoint experiences - are more likely to engage in model-based decision making. These results support the hypothesis that common cognitive mechanisms underlie the learning of latent structure and the goal-directed deployment of knowledge about learned state transitions. References Daw, N., Gershman, S., Seymour, B., Dayan, P., & Dolan, R. (2011). Model-Based Influences on Humans Choices and Striatal Prediction Errors. Neuron, 69(6), 1204-1215.

Adaptive credit assignment in prefrontal cortex

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Introduction In order to make sound economic predictions, the brain needs to appropriately attribute outcomes to their most likely causes. Much real-world learning occurs in structured environments, such as hierarchical systems (e.g. seasonal events, context-dependent rules, social groups) and only the appropriate components should often be assigned credit for an outcome. For example, if you get food poisoning do you attribute it to the burrito you just ate, to the scallops you ate at a particular restaurant last night, or to all shellfish? Although real-world learning in complex environments requires attributing outcomes to latent causes (e.g. all shellfish) and not only recently experienced stimuli and choices made (e.g. the burrito) to learn adaptively, the underlying neural mechanisms remain obscure. Methods We designed a novel choice task composed of 4 choice stimuli (2 presented at a time) and 2 potential outcomes (gift cards) that were grouped into two systems (Fig. 1). Each system comprised a pair of shapes with linked transition probabilities of leading to the two outcomes, if selected. For example, stimulus 1 (S1) predicted outcome 1 (O1) and S2 predicted O2 with the same probability p. S3 predicted O1 and S4 predicted O2 with the same probability q (independent from p). This manipulation means that if choosing S1 leads to O1, a model of the task structure can be used to also learn about the inferred association S2O2 (but not S3 or S4), as both associations are governed by the same latent cause p. Results Behaviorally, logistic regression weights that quantify the influence of past choices and outcomes on current choices indicated that credit for the experienced outcome was given to the chosen stimulus, and credit for the unobserved but inferred outcome was also given to the other paired stimulus that was part of the same system (both $t(21)>5.0$, $p<0.001$). Using a searchlight-based approach to MVPA, we found the past choice identity could be decoded from lateral orbitofrontal cortex, caudate, and lateral occipital complex at outcome time. Conversely, we found a representation of the latent cause at outcome time in mPFC (both $t(21)>3.53$, $p<0.001$ uncorrected). We also identified prediction errors from the best-fitting Bayesian model in dorsal ACC, lOFC, and dorsal frontoparietal areas ($p<0.001$, uncor). Conclusions Collectively, these findings indicate that subjects effectively used a model of the task structure to update the correct predictive association and suggest that different prefrontal regions represent more concrete causal choices (lOFC) and more abstract latent causes (mPFC) to associate with the outcome during credit assignment.

Corticostriatal circuit for strategic behavior by dynamic scaling of action and reward valuation.

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Uncertain environments impose a continuous dilemma between two essential activities: gathering immediate resources in a known capacity, and gathering information to enable better future decisions. Switching between exploration and exploitation is thought to require frontal cortex but the mechanism is not fully known. Neurons in the anterior cingulate cortex (ACC) encode multiple parameters of the decision space and densely project to the dorsomedial striatum (DMS). We hypothesized that ACC projection to the DMS may scale action/reward representations to dynamically control action-outcome valuation in the striatum to enable strategy flexibility. Rats were placed in a figure-eight maze and allowed to choose between a high reward/high cost arm and a low reward/low cost arm. At first, rats alternated between arms (exploration), but then settled on a consistently preferred arm (exploitation) with occasional exploratory bouts. We imaged the activity of DMS projecting ACC neurons (ACC-DMS) at cellular resolution using a GRIN lens and head mounted mini-microscope. ACC-DMS exhibited action and reward related activity that was contingent on the current strategy. Neurons could have either exploration or exploitation preference, but overall the neuronal population exhibited a strategy dependent scaling of action/reward response. Namely, the average response to high reward was higher than the response to low reward (as expected) but only during exploration. This encoding pattern of reward size flipped during exploitation showing significantly higher neuronal activation to the low reward. The same strategy dependent scaling also governed action related responses. Additional group of ACC-DMS neurons was not strategy dependent but rather developed robust activity around the transition to exploitive behavior and signaled the preferred option. These transition neurons changed their spatial preference according to changes in the action-reward space and followed the preferred action-outcome whereas strategy dependent neurons maintained stable spatial representation of the action-reward space even between different sessions spaced days apart. A behavioral model with strategy dependent drift rates, reminiscent of ACC-DMS encoding mechanism, successfully captured behavioral dynamics and predicted future strategy whereas reinforcement learning models with either directed information seeking or random exploration (epsilon-greedy) could not explain animals` behavior. Our results suggest that activity in the ACC-DMS projection may dynamically scale striatal representation of rewards and action-costs according to the current strategy and guide future explore/exploit decision.

The effects of computational complexity on human decision-making

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Most theories of decision-making assume that an observed choice is the outcome of an optimisation problem. They posit that decision-makers always select the best option available. These theories tend to ignore the difficulty of selecting the best option. Where decision difficulty has been taken into account, it has been done either informally or in a highly domain-specific way. Here, we use computational complexity theory, a branch of the theory of computation, to identify the resource requirements - number of computational operations and memory - of decision tasks. We propose instance complexity (IC) as a generalisable framework to quantify difficulty of a decision based on a small number of properties of the decision. This measure has several desirable properties. Firstly, it captures complexity that is intrinsic to a decision task, that is, it does not depend on a particular solution strategy or algorithm. Secondly, it does not require knowledge of a decision-maker's attitudes or preferences. And thirdly, it allows computation of difficulty of a decision task ex-ante, that is, without knowing the solution of the decision task. We tested the relation between IC and decision quality and effort exerted in a decision using two variants of the 0-1 knapsack problem (KP), a canonical and ubiquitous computational problem. Twenty participants from the general population (14 female; age range = 18-31 years, mean

age = 22.0 years) attempted to solve 72 instances of the decision version of the KP and 18 instances of the optimisation version of the KP. We show that participants exerted more effort on instanced with higher IC but that decision quality was lower in those instances. We confirm these findings in two other canonical computational problems, the traveling salesman problem and the satisfiability problem. In a related study, using eye-tracking, we characterise the computational strategies decision-makers use to solve the KP and how they are adapted to changes in instance complexity. In another study, using functional magnetic resonance imaging, we characterise the neural processes involved in adapting to instance complexity and effort allocation. Overall, our body of results shows that the computational complexity of decision tasks, even at low levels, strongly affects decision outcomes. Indeed, our results suggest that existing models of decision-making that are based on optimisation (rationality), are computationally implausible, and that future theories of decision-making will need to account for the computational complexity of decision tasks, with important implications for models of resource allocation in the brain (cognitive control).

Poster Spotlights Abstracts

Friday October 5, 2018

Poster Spotlights I

The cost of cognitive control as a solution to the stability-flexibility dilemma
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Objective: One of the most compelling characteristics of controlled processing is our limitation to exercise it. Theories of control allocation account for such limitations by assuming a cost of control that constrains how much cognitive control is allocated to a task. However, this leaves open the question of why such a cost would exist in the first place. Here, we use neural network simulations and behavioral experimentation to test the hypothesis that constraints on cognitive control may reflect an optimal solution to the stability-flexibility dilemma in neural systems: allocating more control to a task results in greater activation of its neural representation but also in greater persistence of this activity upon switching to a new task, yielding switch costs. From this perspective, constraints on cognitive control may promote cognitive flexibility at the expense of cognitive stability. Methods: We used a recurrent neural network model of task performance and control to explore how different choices of a global control parameter (gain modulation) that constraints how much control can be allocated, influence measures of stability (overall task performance) and flexibility (performance costs associated with task switches) in a task switching environment. We determine the optimal value of this parameter as a function of task switch frequency, by maximizing expected reward across the trial sequence. We also show how optimal constraints on control in the neural network model can be approximated by neuroeconomic models of control allocation that assume a cost of control. Finally, we compare performance of the optimized neural network with performance of human subjects in a cued task switching experiment that we designed to match the task switch rates in the simulation. Results: Our modeling results indicate that higher constraints on control can impair overall task performance but lower task switch costs. Critically, optimal constraints on control are higher in environments with higher task switch rates and can be approximated by a higher cost of control. Performance under such optimal constraints qualitatively matches that of human participants, yielding lower overall task performance but also lower switch costs when task switches are more frequent. Conclusions: This work suggests that constraints on cognitive control can improve cognitive flexibility at the expense of cognitive stability, rendering a high cost of control as optimal in environments with high demands for flexibility. From this perspective, costs associated with cognitive control may reflect, at least in part, an optimal solution to the stability-flexibility dilemma in neural systems

Parsing medial prefrontal cortex: A joint meta-analytic and graph-theoretic approach
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Introduction: Valuation effects are consistently observed in medial prefrontal and posterior cingulate

cortex (mPFC and PCC). The spatial extent of these effects is mostly indistinguishable from the default mode network (DMN) in existing meta-analyses. However, little is known about how valuation effects fit within the broader functional architecture of mPFC and PCC, or whether that architecture is consistent or idiosyncratic across individuals. Here we complement a meta-analysis with fMRI-based graph theoretic approaches to subdivide mPFC and PCC at the single-subject level. This is the first in a series of steps geared to produce more refined topographical targets for studies of valuation. Methods: Regions of interest (ROIs) associated with DMN and valuation were identified from meta-analytic data and projected to a standard cortical surface model. Using fMRI data from the Human Connectome Project, we estimated within-subject resting-state functional connectivity among all surface vertices in the ROIs. We then used two separate community detection algorithms to group vertices that were strongly connected with each other and sparsely connected with other clusters. The resulting partitions were evaluated for consistency across methods, throughout individual time series, and across subjects. Results: Valuation and DMN effects had substantial meta-analytic overlap in mPFC and PCC, with the exception of one PCC subregion that was preferentially associated with the DMN. However, the regions of group-level overlap could be reliably segregated into DMN and non-DMN communities in every individual. PCC subdivisions were well aligned across individuals, whereas in mPFC the subdivisions had low inter-individual transferability despite similar qualitative topological features. Using measures from graph theory and mutual information, we found that different community detection algorithms had strong agreement, and that the topographic patterns were fairly stable throughout each subject's fMRI session. The functional subdivisions did not correlate with subject-specific cortical folding, thickness, or myelin density, and were obscured when aggregated across subjects. Conclusions: Our results suggest the functional topography of mPFC has substantial variability across individuals. This highlights the potential usefulness of estimating brain effects at the individual level in this region, and points to limitations of aggregative methods such as coordinate-based meta-analysis in determining whether valuation and DMN effects emerge from common or separable brain systems. Our approach shows promise in addressing this issue through future manipulations of valuation.

Dorsal anterior cingulate cortex encodes strategy updating in effort-based decision-making

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Integrating cost and benefit information is crucial for optimal decision-making. Prior work has implicated the dorsal anterior cingulate cortex (dACC) as critical for encoding subjective value, choice difficulty, and subjective value prediction errors during cost/benefit decision-making. To date however, it remains unknown how this region uses such processes to create, update, and refine strategies to guide choice behavior and ensure such optimal decision-making. To this end, we recruited participants to complete a sequential effort-based decision-making task while undergoing functional magnetic resonance imaging (fMRI). As part of this task, two runs were manipulated to contain trials with subjective values that were significantly above (high reward) or below (low reward) participants' indifference points. In these runs, participants developed clear choice preferences to either accept or reject the Effort Option, respectively. We observed greater dACC activity when participants chose the option that deviated from their default choice preference, suggesting a role in encoding shifts in choice strategy. This pattern was strongest for low reward trials that fell below participants' indifference points. These results suggest a broader role for dACC to encode deviations and strategy updating in economic decisions. This region and this particular role may prove critical in furthering our understanding of disrupted decision-making so often observed in psychiatric disorders.

A neurocomputational account of corruption

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Introduction: Corruption is defined as the abuse of entrusted power for private gains at the expense of others' interest via dishonest conduct. While this topic has been investigated extensively in the past years, its neurocomputational mechanisms remain poorly understood. Hence we performed a behavioral study (N = 28) and an fMRI study (N = 40) by adopting a novel paradigm with computational modeling. Methods: Participants were assigned the role of an arbitrator and informed that an independent online group study had participated in an early study where they played a sender-receiver game. This game consisted of two roles, i.e., a sender and a receiver. Senders played either by themselves (solo context) or with randomly-matched receivers in other cases (dyad context). In the solo context, each sender presented with two options earning themselves different payoffs. In the dyad context, each sender was presented with two options with different payoffs distribution between him-/herself and a receiver. Although senders were requested to always honestly report the option pre-determined by the computer, it was still possible for them to report the alternative options (i.e., telling a lie) to benefit themselves. Importantly, senders could bribe arbitrators at their own cost to persuade the latter to approve their decisions. The task for the participants (arbitrators) was to decide whether to accept the bribe or not. If they accepted it, the sender's decision would be approved, which benefited both the arbitrator and the sender (this also harmed the receiver in the dyad context). Otherwise, the sender's decision would not be approved and neither of the arbitrator nor the sender could earn money (receivers would thus be paid according to the selected option). Results: Behaviorally, participants felt more morally inappropriate to accept and thus more likely to reject the bribe when the sender deceived (vs. honesty) in the dyad (vs. solo) context. Model comparison favors the social preference model including not only the inequity aversion but also the moral concern for probity and victim. At the brain level, value signals presiding (corruptive) choices were encoded in the valuation network (vmPFC, dACC, and PCC). Dishonesty-enhanced value signals in the right AI were modulated by individual difference in probity concern. Moreover, decision-relevant activities were stronger in rostral ACC when the sender deceived (vs. honesty) and such neural difference increased in lateral OFC in the dyad context. Conclusion: Our findings provided the first characterization of the neurocomputational mechanisms guiding corruptive behaviors.

Is attention mediating the memory bias in preferential choice?

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Many decisions rely on past experiences. Recent research indicates that people's decisions are biased toward choosing remembered options, even if these options are comparatively unattractive (Gluth, Sommer, Rieskamp, & Büchel, 2015). In the current study, we investigated whether visual attention (fixations) serves as a potential mediator for the memory bias in preferential choice. Our specific hypotheses were that people pay more attention to remembered options and that people prefer options they have looked at longer (Krajbich, Armel, & Rangel, 2010). In our study, N = 37 participants completed a two-session within-subject eye-tracking study. In both sessions, participants learned the association between locations on the screen and various food snacks. After a delay, they made decisions between options that they either saw directly (non-memory-based decisions, NMB) or that they had to retrieve from memory (memory-based decisions, MB). Last, we assessed which options they could remember. The two sessions differed in terms of whether participants saw both options simultaneously or sequentially (i.e., one after the other). Our results indicate that participants did not pay more attention

to remembered compared to forgotten options. However, we found that the tendency to choose the last-fixated option was even stronger in MB decisions than in NMB decisions. Furthermore, when presenting options sequentially, participants showed a preference for the second option in MB but not in NMB decisions. Consequently, these two effects may arise from an increased impact of attention on MB decisions, although it does not mediate the memory bias. To predict choices and response times as well as to describe the interplay of attention, memory, and decision-making we will use the attentional Drift Diffusion Model (aDDM; Krajbich et al., 2010). The aDDM assumes that people consider advantages and disadvantages of the available choice options in a stochastic accumulation-to-bound process. In addition, the aDDM includes a bias in the accumulation process towards the fixated option. We will present behavioral, eye-tracking and computational modeling results and discuss the findings in light of their meaning for everyday decisions. As decisions seem to be biased by memory and attention, integrating those effects in a common framework may help to improve policies that aim to support people to make more adaptive decisions.

Saturday October 6, 2018

Poster Spotlights II

Using a two-player interactive game to study strategic competition, its neuronal correlates, and the effects of a third observer

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Primates including humans exhibit complex behaviors when interacting with their conspecifics. Laboratory studies of primate sociality, however, routinely employ choice tasks in restricted action space, affording poor external validity and limited numbers of behavioral markers to compare across species. In the current study, we preserved the dynamic nature of social interactions by examining the simultaneous, continuous behaviors of pairs of humans or rhesus macaque monkeys playing a zero-sum competitive soccer game. To win a point, one player (the kicker) had to maneuver a ball across the screen while the other player (the goalie) attempted to intercept it. We found that in this game the interactions between human pairs (n = 9,000 trials) and monkey pairs (n = 11,600 trials) were similarly complex, and this complexity could be disentangled and reliably categorized into a set of strategies: overall, the kicker won by being unpredictable whereas the goalie won by accurately responding to the kicker's movements. Even though the interaction between players ultimately dictated the game, gaze patterns and pupil sizes in both players predicted ball position and trial outcome before either player started to move. In monkeys, we also recorded single unit activity from a subregion of Superior Temporal Sulcus (mSTS), a potential homologue to human Temporo-parietal Junction (TPJ). We found that for both kicker (n = 133) and goalie (n = 125) mSTS neurons signaled strategy during the task phase and trial outcome during the reward phase. In addition, mSTS differentiated between social contexts (kicker n = 772 neurons in 5 conditions, goalie n = 432 neurons in 3 conditions) and was most robustly activated by competition with live opponents, even in the absence of visual social cues. Finally, we found that adding a third observer monkey to the game and randomly assigning him to either the kicker or the goalie's team (and thus getting rewarded together with his teammate) greatly impacted behavioral performance as well as mSTS activity in the players. Specifically, when the observer was put on the kicker's team, the kicker won more frequently and mSTS signals associated with strategy and trial outcome were amplified. We also found that spiking and LFP activities in the kicker de-correlated from those in the goalie when

the observer was on the kicker's team. Together, these results demonstrate the feasibility of using two-player interactive games to study complex social behavior, strongly implicate the primate mSTS in encoding the strategies of self and others during live interactions, and support the hypothesis that this area is the homologue of the human TPJ.

Neuromodulatory and structural substrate of intertemporal choices in younger and older adults

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The neuromodulatory and structural brain basis of interindividual differences in how people discount future rewards is not yet well established despite its vast importance for understanding both healthy functioning and psychiatry disorders. Here we present results from behaviour and neuroimaging analysis from two human cohorts. For each participant, we assessed delay discount rates fitting a hyperbolic model to data from a standard intertemporal choice task. We also generated maps of grey matter volume (GMV) and fractional anisotropy (FA, a measure of white matter microstructure organization) and estimated the volume of subcortical brain structures as well as total cortical volume. In the first sample (903 younger adults, 22-37 y from the Human Connectome Project dataset), more impulsive discounting was associated with smaller total cortical volume and putamen volume. We also decomposed the GMV and FA data in structural covariance networks using independent component analysis. More impulsive discounters had less GMV in in a network loading primarily on bilateral temporal pole and middle-temporal regions, but higher FA in a network loading mainly on frontal white matter overlapping with the uncinate fasciculus and the forceps minor. We then projected the GMV and FA data of the second sample of 30 younger (19-32 y) and 30 older (66-75 y) adults onto these two structural networks. In this sample, older individuals discounted future rewards significantly more than younger ones, and had reduced GMV and FA values in the identified structural networks. FA values in the frontal white-matter component were positively correlated with discount rates after controlling for age, as in the first sample. We also estimated dopamine D1 receptor binding potential (BP) using the tracer [11C]-SCH23390 and found a positive age-corrected association between discount rate and D1 BP for the pallidum. These results link choice impulsivity to cortical and subcortical grey matter volumes, and to the microstructural organization of frontal white matter and dopamine neuromodulation in the basal ganglia. Both microstructural organization and dopamine neuromodulation predict delay discounting independently of their reduction with age.

Effects of commercial break interruption on EEG frontal alpha asymmetry and program recall rate

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Many neuromarketing studies have examined the effect of TV commercials on psychological processes such as memory and pleasantness. However, little has been studied on interruption by commercial breaks (CBs) even though they can cause negative feelings on TV programs or commercials. The aim of this research is to explore the impact of CB on TV programs and commercials with respect to memory and enjoyment. We performed electroencephalography (EEG) experiments in 51 subjects while they watched two 30-min programs, a drama and a variety show, and twelve 30-sec commercials in total. 26 participants (i.e. CB group) watched the program that was interrupted by CBs twice: one at one-third and the other at two-third of program. Each interruption contained three commercials. The rest of participants (i.e. control group) watched three commercials before and other three after the program. After watching two programs, they were asked to answer the enjoyment level in a 7-scale. About a week later, participants were asked to answer the questions that they had not been informed: enjoyment level

for programs, recall of programs and commercials, recognition of programs and commercials, and evaluation of commercials. The result of commercial evaluation showed that twelve commercials were not different with respect to purchase intention, model likeness, and self-assessment of attention indicating that the saliency of commercials were well controlled and that any of them would produce the same amount of feelings of interruption. The CB group exhibited a poorer recall rate for the programs, especially the variety show than the drama, compared to the control group. But no significant difference in the recall rate was found for the commercials. Then, we analyzed EEG data using the power spectral density (PSD) of alpha oscillations (8-12Hz) that was calculated for each one-third segment of the data during viewing the variety show. Alpha power was z- transformed to calculate EEG frontal asymmetry (F3-F4). Two-way mixed repeated measures analysis of variance (ANOVA) was conducted with one within-subject factor, sequences of program (first, middle, last) and the other between-subject factor, experiment group (CB vs. control). A marginal interaction effect was observed, showing increased left frontal activity in the control group only in the last part of the programs. In summary, this study suggests that when TV viewers are interrupted by commercials while watching a program they would feel less pleasant and recall the programs, but not commercials, less accurately.

Parsing the role of dopamine in reward discounting and subjective valuation

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Some people are more willing to make impulsive, risky, or costly choices than others, which has been assumed to be strongly associated with individual differences in dopamine (DA) function. Much attention has focused on DA D2 receptors, which inhibit impulsive motor action and are implicated in motivation-related tonic DA signaling. Similarly, discounted subjective value representations in the ventromedial prefrontal cortex (vmPFC) are believed to be driven by dopamine signaling. However, few studies offer clarity on the association between DA D2 receptors, discounting behavior, and the neural representation of subjective value. In a multimodal brain imaging study and two meta-analyses, we sought to clarify these associations. We scanned 84 healthy adults with PET imaging and [18F]fallypride, a radioligand that binds to D2 receptors in the striatum. A subset of these participants (N=22) completed a delay discounting task during an fMRI scan. In the larger sample, striatal D2 receptor availability was not directly correlated with discounting behavior. In the subset of subjects that completed both PET and fMRI, we identified a novel link between D2 receptors in the ventral striatum and subjective value representation in the vmPFC. A follow-up meta-analysis of studies of individual differences in DA PET measures and discounting in humans (N=17 effects) corroborated our null findings between striatal D2 receptors and discounting behavior, but also suggested that the nature of individual difference associations between DA and discounting depends on DA-related psychopathology. In a second meta-analysis, we examined the impact of pharmacological manipulation of the DA system from placebo-controlled studies of discounting using humans, non-human primates, and rodents (N=61 effects). DA drug effects suggested a more nuanced relationship between DA receptors and reward discounting with non-significant differences in effects on discounting between agonist and antagonist drugs that bind to D1 or D2 receptors. Alternatively, drugs that bind to DA transporters, which clear extracellular DA, consistently decreased reward discounting. Together, the data suggest that the relationship between individual differences in DA receptors, discounting, and neural representations of value are not as clearly linked in healthy humans as many in the field have assumed. The strongest associations were observed between DA receptors and neural representations of subjective value but overall, in our own data and across the existing literature, there were no reliable direct associations between DA D2 receptors and discounting behavior in healthy humans.

Crowdsourced science: Analyzing variability in data analysis in neuroscience

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Trust in scientific knowledge comes from the ability to replicate empirical findings. However, the recent "replication crisis" in many sciences calls into question previously published results. A large share of false positive results can be caused by the many "researcher degrees of freedom" where results can be "trimmed" towards desired outcomes in the data analysis process. Recently, an attempt by Silberzahn and Uhlmann (2015) investigated how different teams of researchers arrive at different conclusions about the same data set in psychology. Similarly, in neuroscience there is an increasing debate about low statistical power and interpretational problems of fMRI data where researchers have some "freedom" in searching (intentionally or sub-consciously) for desired results. In our study we aim to provide the first scientific evidence on the magnitude of variability of results across analysis teams in neuroscience. In particular, we collected fMRI data from n=110 participants on two versions of the mixed gambles task (Tom et al, 2007). On each trial, a mixed gamble was presented (one gain amount, one loss amount) and the participants decided to accept the gamble or not. Each participant performed one of two conditions: In the equal indifference condition, the matrix of gambles included potential gains twice the range of potential losses (Tom et al., 2007); in the equal range condition, the matrix included an equal range of potential gains and losses (De Martino et al., 2010). For the data analysis process we aim to recruit around 30-40 research groups in neuroscience. These groups will be given the raw data to independently estimate the brain activations according to ex ante hypothesized brain regions. We predict activations in several regions for specific contrasts, based on previous results (Tom et al., 2007; DeMartino et al., 2010) and analysis teams will freely analyze the dataset to answer the hypotheses. The main outcome variables will be the number of teams reporting a significant result and the variation in brain activations across teams. Finally, we will measure peer beliefs about the main outcome variables by running prediction markets. Similar to our previous studies (Camerer et al., 2016, 2018) experimental subjects (recruited among researchers in neuroscience that are not part of the analysis teams) will trade on the outcome of our hypotheses. We will run 2 prediction markets for each hypothesis: (i) the fraction of teams reporting significant results and (ii) the variability of analysis results across teams. Trading on the prediction markets will be incentivized. The goal of this abstract is to recruit the analysis teams.

Sunday October 7, 2018

Poster Spotlights III

How do we build causal models of the future? Evidence from gaze patterns

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OBJECTIVE Many everyday decisions require foreseeing the occurrence of future events and their direct and indirect consequences. In these situations, the way agents build models of the contingency space might affect their ability to respond to potential states of the world. However, it is not clear how agents encode and organize available information to react to future circumstances. In the present study, we

investigated the process of generation of contingency models by tracking eye movements of participants who performed a novel causal-inference task. METHOD In the causal-inference task, participants had to learn deterministic conditional rules regulating the occurrence of interdependent events. After the occurrence of one such event, they had to infer all the conditions that would have followed. We performed within-trial cluster analyses on gaze data to isolate mechanisms specifically related to the processes of encoding and integration of relational information, disentangling them from working memory functions. These gaze patterns were used to identify how agents integrated interdependent pieces of information and thus what type of internal causal model they were building. RESULTS A between-subject cluster analysis on early gaze data revealed the existence of two distinct types of participants in the causal-inference task. A group of (sophisticated) participants systematically searched for both direct and indirect relations between states, building an exhaustive model of the contingency space. Another group of (unsophisticated) participants simply learned binary conditional rules without exploring the existence of second-order relationships between conditions, trying to infer the consequences of an event only after its occurrence. The emergence of these two types of behavior largely explained the ability to predict the occurrence of future events. Analyses of individual cognitive measures revealed that cognitive reflection is associated with the emergence of either sophisticated or unsophisticated representation behavior, while working memory and fluid intelligence modulated performance independently of the type of visual analysis implemented. CONCLUSION Our results reveal the existence of two spontaneous processes of generation of causal models of future events. Since building efficient causal models of contingencies is crucial in several learning and decision-making settings, we believe that our novel gaze-based approach could be used in future research to disclose the sources of heterogeneity in several types of economic behavior.

Biased belief updating and suboptimal choice in foraging decisions

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Objective: Foraging theory prescribes an optimal solution to choices that involve comparing the value of an option against an estimate of how prosperous our environment is. But a separate domain of research has revealed that individuals do not always form beliefs about their environment in an unbiased manner. Instead they prefer to integrate information that suggests their environment is better compared to worse than expected. Here we demonstrate how biases in belief updating can manifest themselves in foraging decisions. In doing so we explain a phenomenon with overreaching societal impact - a reluctance to adapt choices when times are tough. Methods: In a series of studies we combined the computational framework of reinforcement learning with a classic prey selection task from foraging theory in which individuals decided whether to accept or reject sequentially encountered stimuli. Accepting resulted in a reward but also incurred a time penalty. By varying the availability of different types of stimuli we manipulated how rich/poor the environment was and examined whether participants' choices were sensitive to these fluctuations. We modelled choices as the result of a learning process in which individuals maintained an estimate of their environments global reward rate. The specific task structure enabled us to investigate whether trial by trial adjustments to this estimate depended on whether the environment was improving (getting richer) or deteriorating (getting poorer). Results: In rich environments, participants preferentially targeted the most profitable options. In poor environments, they became less selective and accepted less profitable options. These shifts in preferences were observed in response to both local (within block) and global (between block) fluctuations. Crucially however, they were larger when the environment improved compared to when it deteriorated. Choice data was best described by a computational model in which a global reward rate estimate was scaled up

or down according to separate learning rates. This enabled the estimate to update sluggishly when the environment deteriorated (causing preferences for options to perseverate) but quickly when it improved (causing preferences to adapt and change). Conclusion: A failure to adjust expectations when an environment becomes worse leads to suboptimal choices. Valuable options are rejected in the false expectation that better options will materialize. Our findings suggest that this tendency arises out of a learning process in which individuals update beliefs about their environment differentially depending on whether outcomes suggest the environment is getting better or worse.

Comprehension as Bayesian decision-making: neural computations of inferring what is meant from what is said in language games

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Communication is a ubiquitous feature of social interactions across multiple species. A cornerstone of effective communication is the ability to recognize the intended message of a speaker for a listener (a.k.a., speaker meaning) even though that message is often not coded in the utterance directly. A number of theoretical and behavioral models of pragmatic reasoning have been proposed, in particular the rational speech act, which connects pragmatic inferences with probabilistic inferences by drawing on formal decision models such as the Bayesian theory. Here, we investigate the cognitive and neural substrates of pragmatic reasoning by exploring brain regions that encode model-derived inference signals used to decipher speaker meaning in a stylized communicative setting. Specifically, we examined the fMRI data of a language game where a listener needs to infer a target object in a given context based on a message received from an anonymous speaker. Behavioral analyses show that the process of inferring a speaker's intended referent can be characterized as a Bayesian decision process, which integrates the prior information with a mentally simulated likelihood for speaker's actions. Consistent with the behavioral model, imaging data reveal that the latent likelihood signal derived from the model is expressed in the ventromedial prefrontal cortex (vmPFC), even when Bayesian reasoning is unnecessary for discerning speaker meaning (e.g., when speaking meaning is explicitly coded in the utterance). Interestingly, this region also demonstrates model-dependent connectivity with a number of brain regions, including the dorsomedial prefrontal cortex and temporoparietal junction, which are known to be involved in theory-of-mind, and the left inferior frontal gyrus, which has been repeatedly implicated in language processing. The robustness and specificity of the observed behavioral and vmPFC response patterns are further demonstrated in two additional experiments. Together, these results provide a neuromechanistic account of pragmatic reasoning where effective language interpretation arises from a Bayesian decision process, and the vmPFC plays a central role in inferential computations critical for Bayesian reasoning. The data point to a new avenue that bridges the literature of model-based decision neuroscience and that of language and social communication.

Context-sensitive judgment reflects efficient coding of economic attributes

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Descriptive accounts of decision making such as expected utility theory are typically based on a stable set of "psycheconomic" functions specifying the mental representations of economic attributes. However, the psychological reality of such functions has been challenged by evidence that decisions are highly context-sensitive: the mental representation of an attribute value changes depending on the choice set and other attribute values retrieved from memory. One influential theory--decision by sampling (DbS)--proposes that an attribute's subjective value is its rank within a retrieved contextual sample. Here, we provide a normative justification for DbS that is based on the principle of efficient

coding. According to this principle, the brain is designed to represent information in ways that economize on our limited neural resources. When neurons are conceived as noiseless communication channels, the efficient representation of information is achieved by a code that minimizes redundancy in neuronal responses. Redundancy minimization requires values to be encoded so that they are uniformly distributed across the response space, which is implemented by the rank transformation of DbS. Context sensitivity may thus arise for the same computational reason in both judgment and perception: our brains must compress the world as best as possible across different environments. However, when inherent cognitive constraints entail that only a finite decision sample can be retrieved, information transmission is impaired. We theoretically specify the problems caused by finite samples and show how efficiency is partly restored by smoothing of the signal, a principle that indicates new ways to generalize DbS. Such generalizations are closely connected to range-frequency theory, which we derive as an optimally kernel-smoothed estimate of rank. Accordingly, this approach can account for sensitivity to the range of attribute values as has been documented in a variety of behavioral settings. Furthermore, our analysis provides a normative rationale consistent with efficient coding for why neurons in orbitofrontal cortex that represent subjective value exhibit quasi-linear tuning curves even when traditional analyses predict nonlinearity. Moreover, we demonstrate that optimal smoothing can explain how context sensitivity is affected by the number of available response categories. We also show how kernel smoothing may psychologically present as reduced discriminability between items in memory, which could help account for phenomena such as compromise effects. Thus, a deeper understanding of why context sensitivity occurs enables us to better predict its properties.

Applying marketing research methods to decision-making in the criminal justice system

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Examples of wrongful convictions in the U.S. have sparked widespread efforts to understand and improve decision-making in the criminal justice system. Here, we show that an experimental approach adopted from marketing research can replicate effects on judgments of guilt or innocence that have been shown to be important risk factors for error in real criminal prosecutions. Our approach combines a high-throughput behavioral task with hierarchical Bayesian analysis, similar to conjoint analysis used in marketing, to quantify the effects of crime type, evidence, and other variables on confidence in a defendant's guilt. In our first study, for example, we described 33 crimes, which varied in seriousness from shoplifting to rape and murder. Each crime could be combined with 18 combinations of evidence, including forensic evidence; eyewitness identification; and/or a suspect's prior convictions. For each crime scenario, an individual subject views one randomized combination of evidence; across subjects, all combinations of crime type and evidence are represented. This produces partially-overlapping changes to the scenarios, so that we can estimate the effect size and variance for each subject, each crime, and each type of evidence. Data for subjects who did not see a particular combination of evidence in a particular scenario are treated as missing and estimated using hierarchical Bayesian modeling. Across all subjects, confidence in guilt depended most strongly on the evidence directly linking the accused to the crime. Independent of the evidence, however, the type of crime affects baseline confidence in guilt, and the magnitude of this bias is positively correlated with the seriousness of the crime. For mock jurors (Amazon Turk), baseline confidence in guilt for the most serious crimes is as large as the effect of an eyewitness identification. Prior convictions had a modest but significant effect. Consistent with these results, studies of real criminal cases show that, where the direct evidence is ambiguous, the likelihood of conviction increases when the crime is very serious and the defendant has a criminal record. The

results show that an experimental approach borrowed from marketing can approximate aspects of decision-making known to be important in real criminal cases. This approach complements traditional methods in criminal justice research by allowing rapid, cost-effective studies that can quantify effects of individual variables in a high-dimensional parameter space and by replicating risk factors for errors in criminal justice in a format compatible with brain imaging and other methods for investigating the brain mechanisms involved.

Poster Abstracts

Friday, October 5, 2018

A. Attention

1-A-1 The cost of cognitive control as a solution to the stability-flexibility dilemma

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Objective: One of the most compelling characteristics of controlled processing is our limitation to exercise it. Theories of control allocation account for such limitations by assuming a cost of control that constrains how much cognitive control is allocated to a task. However, this leaves open the question of why such a cost would exist in the first place. Here, we use neural network simulations and behavioral experimentation to test the hypothesis that constraints on cognitive control may reflect an optimal solution to the stability-flexibility dilemma in neural systems: allocating more control to a task results in greater activation of its neural representation but also in greater persistence of this activity upon switching to a new task, yielding switch costs. From this perspective, constraints on cognitive control may promote cognitive flexibility at the expense of cognitive stability. Methods: We used a recurrent neural network model of task performance and control to explore how different choices of a global control parameter (gain modulation) that constraints how much control can be allocated, influence measures of stability (overall task performance) and flexibility (performance costs associated with task switches) in a task switching environment. We determine the optimal value of this parameter as a function of task switch frequency, by maximizing expected reward across the trial sequence. We also show how optimal constraints on control in the neural network model can be approximated by neuroeconomic models of control allocation that assume a cost of control. Finally, we compare performance of the optimized neural network with performance of human subjects in a cued task switching experiment that we designed to match the task switch rates in the simulation. Results: Our modeling results indicate that higher constraints on control can impair overall task performance but lower task switch costs. Critically, optimal constraints on control are higher in environments with higher task switch rates and can be approximated by a higher cost of control. Performance under such optimal constraints qualitatively matches that of human participants, yielding lower overall task performance but also lower switch costs when task switches are more frequent. Conclusions: This work suggests that constraints on cognitive control can improve cognitive flexibility at the expense of cognitive stability, rendering a high cost of control as optimal in environments with high demands for flexibility. From this perspective, costs associated with cognitive control may reflect, at least in part, an optimal solution to the stability-flexibility dilemma in neural systems.

1-A-2 Modeling motivational influences on sustained attention

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Objective: Achieving our goals often requires sustained focus, such as ignoring distractions while writing a conference abstract. This focus is known to wane with time, a phenomena called vigilance decrement. Recent studies suggest that this decrement is not a fixed limitation, as incentives can lead to overall performance improvements and/or diminished vigilance decrements (Esterman et al., 2014, 2016). However, the cognitive mechanisms driving these motivational effects remain unclear, including how

they influence sensory processing and strategic responding. Here, we test a process model of sustained attention in order to better characterize its constituent processes. Methods: We re-analyzed Esterman and colleagues' (2014, 2016) experiments, in which participants performed 10-minute sustained attention tasks involving continuously morphing stimuli. Participants were required to respond to one stimulus category (90% of trials) and withhold responses when the other stimulus category appeared. Participants were incentivized with either no reward, performance-contingent reward on each trial (fixed reward), or a potential large loss on an unknown future trial (anticipated reward; n=30 per group). No-reward participants performed worse overall and exhibited a vigilance decrement over time. Fixed-reward and anticipated-reward participants performed better overall, though only the anticipated-reward group lacked a vigilance decrement. We modeled task performance with a novel time-varying drift diffusion model (DDM) in which the evidence accumulation (drift) rate varied with the visibility of the gradually morphing stimulus. Attentional control was parameterized as influencing the peak drift rate and the response threshold. We fit this model to behavior in each of the reward groups using hierarchal Bayesian estimation. Results: Our time-varying model predicted behavior better than the standard (stationary) DDM across all groups, as well as in a large online sample (n=21,400, no reward; Fortenbaugh et al., 2016). Comparing incentive conditions, we found that drift rate and threshold were higher for rewarded groups than the no-reward group. Over time, drift rate and threshold decreased in the no-reward and fixed-reward groups, but these decrements were absent in the anticipated-reward group. Conclusions: Informing the debate on the control and constraints of sustained attention, we found that both sensitivity and caution increased with reward and that their decrement was attenuated in the anticipated reward condition. These results improve our understanding of the mechanisms and temporal dynamics underlying motivation-attention interactions.

B. Emotion & Affect

1-B-3 Exploring value-based encoding in the dorsomedial striatum

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As neuroeconomic approaches to decision-making have flourished, there is increasing interest in the cellular and circuit-level neural mechanisms that support value-based action selection. The striatum has been shown to play a critical role in regulating voluntary motor output and goal-directed decision-making via a combination of local lesion studies, anatomical dissections and targeted pharmacology. While studies have suggested representation of action values in individual striatal neurons, thus far, no studies have demonstrated physiological correlates of value-based choice in specific striatal MSN sub-populations. Here, we detail a novel paradigm allowing us to investigate mouse cognition as it relates to econometric decision-making, with a focus on how benefits and costs are integrated to modulate action selection. We developed global and individual trial measures to assess the choice patterns and behavioral flexibility of mice in response to differing "choice benefits" (modeled as varying reward magnitude ratios) and different modalities of "choice cost" (modeled as either increasing repetitive motor output to obtain reward or increased delay to reward delivery). We demonstrate that mouse choice is highly sensitive to the relative benefit of outcomes and that choice costs are heavily discounted in environments with large discrepancies in relative reward. We then used this behavioral framework as a foundation to analyze in vivo population calcium imaging recordings of D1 and D2-dopamine receptor-positive spiny neurons in the dorsomedial striatum of awake-behaving mice. Past pharmacological studies have suggested that these sub-populations may mediate dissociable aspects of value-encoding, namely, the processing of reward benefits and costs, respectively. Our preliminary findings suggest that while coordinated ramping activity prior to the onset of an action sequence is correlated with the

benefit of that action for both cell types, the D2 population, in particular, alters its firing pattern in response to differential effort requirements.

1-B-4 Intuition as starting point bias in sequential sampling models of social decision making

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Social decision making pervades our everyday life and involves balancing conflicts between selfishness and pro-sociality. The cognitive processes underlying such decisions are not well understood, with some arguing for a single comparison process, while others argue for dual processes (one intuitive and one deliberative). Here we propose a way to reconcile these two opposing frameworks. We argue that intuition can be seen as a starting point bias of a sequential sampling model (SSM) process, analogous to a prior in a Bayesian framework. We study the implications of this model using a series of mini-dictator games in which subjects make binary decisions about how to allocate money between themselves and another participant under time-free, time-pressure, and time-delay conditions. We find that subjects are heterogeneous in whether they are biased towards selfishness or pro-sociality. In particular, pro-social subjects become more prosocial under time pressure and less pro-social under time delay, while selfish subjects do the opposite. The cognitive processes of social decision making comply with SSMs, even under time pressure and time delay. We test our model using out-of-sample predictions, revealing that it has higher predictive power than the standard unbiased SSM and some logistic choice models. Our findings help to resolve the current debate and reconcile the conflicting results concerning the cognitive processes of social decision making, and highlight the importance of modeling the dynamics of the choice process.

1-B-5 Neural, behavioral, and computational effects of effort discounting and fatigue in major depression

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The objective of this study is to evaluate effects of effort discounting and fatigue in individuals with depression during effort-based decision-making. Depression has been associated with reduced willingness to engage in effortful behavior and reduced goal-directed activity. Effort-based decision-making paradigms have been used in many psychiatric populations, including major depression, to evaluate cost-benefit decisions that contribute to decreased motivation. Here, we examine effort-based decision-making in individuals with major depression (n=21) and matched healthy controls (n=21) using an fMRI-adapted effort-discounting paradigm where participants choose between options of varying amounts of effort (speeded button presses) in exchange for monetary reward. Computational modeling of choice behavior suggests a difference between individuals with depression and healthy controls in the rate at which reward is devalued by required effort, consistent with increased discounting for moderate effort levels. In the fMRI data, participants with major depression showed reduced striatal (small volume corrected, $p<.05$) and dorsal anterior cingulate (cluster corrected whole brain, $p<.05$) activation relative to healthy controls when choosing to accept higher effort options. Within the depressed patients, fatigue measured with Brief Fatigue Inventory correlated with striatal signal when choosing effort, where higher fatigue was associated with lower striatal activation. This effect remained significant when controlling for reward value. Results suggest altered cost-benefit decision-making in major depression that may contribute to commonly observed motivational deficits.

1-B-6 Keep or switch: Modelling the context-dependent changes of introducing a default option to food choices.

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Introducing a default option into a choice set biases choice in many domains, from organ donation to financial investments. There has been little research, however, on the mechanisms by which a default influences dietary choices. In two experiments, we examined the effect of defaults on food choice both with (Experiment 1, N = 41) and without (Experiment 2, N = 52) priming participants to attend to either the taste or health attribute of foods. In both experiments, participants chose the default option more than the alternative, even when it was the more disciplined option (i.e., healthier and less tasty). This suggests that the introduction of a default into a choice set can promote more disciplined choices. Given that the default was chosen more often, we expected to find shorter reaction times indicative of a faster decision process in the default condition. Counterintuitively, however, in both experiments response times were longer in the default condition than in the control in no-prime and taste-primed participants. This suggests that the default changes behavior by modulating the decision process rather than by engaging a heuristic. We modeled the decision process using single and multi-attribute drift diffusion models (DDMs) which allowed us to translate choice and response time into components of cognitive processing. We found several DDM parameters, like bounds, explained both the observed increases in response time and individual differences in the proportion of healthy choices. Additionally, our multi-attribute model revealed - for both Experiments - that introducing a default option slowed down the processing of the taste attribute, giving health an added advantage and allowing for the increased number of healthy choices in the default condition. Taken together, our findings lead to the counterintuitive conclusion that introducing a default to a food choice engages a more deliberative decision process - which may in turn potentiate healthful food choices.

1-B-7 Model-free or muddled models in the two-stage task?

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Objective: Choice patterns in the two-stage task developed by Daw et al. (2011) suggest that the human brain employs both model-free and model-based learning. However, another possibility is that the apparent model-free influence is caused by model-based learning operating with an incorrect model of the task. We sought to test this hypothesis. Results: Model-based agents operating with the wrong task model can appear to be partially model-free. Specifically, we ran simulations of purely model-based agents performing a two-stage task and found that logistic regression and reinforcement learning model fitting erroneously classified the agents as model-free/model-based hybrids. Facilitating the use of the correct two-stage task model drastically increases model-based behavior in human participants. We ran two separate experiments with improved instructions (version 1 N = 21, and version 2 N = 24) that relied on detailed stories and explained the causes for every event in the two-stage task to increase the likelihood that the participants would understand and use the correct task model. In both experiments, the task had the same stage transition and reward probabilities (and hence the same tradeoff between accuracy and effort) as the original two-stage task. Following Daw et al. (2011) and others, we analyzed pairs of consecutive trials to compute the probability of repeating the same first-stage action on the next trial as a function of the reward and transition between stages in the previous trial. The coefficient for the reward by transition interaction, an indicator of model-based learning, was 5.9 times larger for both versions of our instructions (95% CI [4.7, 7.2]; 95% CI [4.5, 7.3]) compared to that found in data from a replication of the original two-stage task by Kool et al. (2016). We also fit a hybrid model-based/model-free reinforcement learning model to the data and found that the median model-based weight, another indicator of model-based learning, was 0.81 for both versions of our instructions, which is greater than

that found in participants from Daw et al. (2011), 0.39, or Kool et al. (2016), 0.27. Lastly, we found that participants showed a tendency toward exploratory behavior that is not accounted for in the traditional hybrid model. Conclusion: Changing the instructions for the two-stage task to a detailed story can increase model-based behavior. Our results suggest that apparent model-free behavior in the two-stage task can be caused by confusion about how the task works leading participants to employ the wrong model of the task structure or perhaps search through a series of incorrect models over time.

1-B-8 Dopamine modulates regret avoidance in economic choices

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It has been demonstrated that economic choices are not only driven by expected value and variance, but also affected by the anticipated regret, which is a counterfactual measure of the worst possible outcome associated with certain option (relative to the counterfactual outcomes of other options). Previous neuroimaging and lesion research has shown that brain regions (i.e. orbitofrontal cortex) receiving heavy dopamine projections are involved in the assessment of anticipated regret during decision-making. However, the specific effect of dopamine on anticipated regret is still unclear. Here, we used a double-blind, placebo-controlled and within-subject design pharmacologic experiment to investigate the relationship between dopamine and anticipated regret in healthy male participants. Participants performed a gambling task under the administration of madopar (L-Dopa, a precursor of dopamine), haloperidol (an dopamine D2 receptor antagonist) and placebo with the sequence counterbalanced across subjects. We simultaneously tested dopamine effect on the anticipated and experience regret by measuring subjects' choice as well as self-report emotional states via partial and complete feedback sessions where subjects had the opportunities observing only the outcome of selection choice and outcomes of both options, respectively. We applied a mixed-effect logistic regression model to estimate the impact of option's expected value, standard deviation, and anticipated regret on the choice, and then respectively examined the effects of dopamine on these predictors. We found that dopamine level regulated the impact of anticipated regret, but not the expected value or standard deviation. Specifically, increasing dopamine levels enhanced the weight of anticipated regret compared to placebo both in partial and complete feedback sessions. However, reducing dopamine levels decreased the weight of anticipated regret in partial feedback, but didn't significantly differ from the placebo condition in complete feedback session. In summary, our findings revealed a modulation effect of dopamine on regret avoidance.

1-B-9 Differences in cognitive effort discounting and delay discounting processes

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Heightened preferences for small, immediate over larger, later rewards (delay discounting) have been associated with numerous psychopathologies including substance use disorders and ADHD, but a similar choice structure focused on cognitive effort is less studied; despite its possible association with grit and perseveration. A preference for small rewards requiring less or negligible cognitive effort over larger rewards requiring more cognitive effort may be associated with apathy, while the opposite decision making bias may be associated with success overcoming psychological obstacles, such as cravings during drug use cessation. To compare these two decision paradigms, we compared discount curve fits, decision times, and eye tracking data for a standard delay discounting task and a novel cognitive effort discounting task. Fifty-seven male and female volunteers practiced an effortful, sustained attentional task for 1 minute. They then answered hypothetical questions on their preferences between money rewarded after 0-min effort on the attention task or $25 after 1, 5, 10, or 20 minutes. They also

answered hypothetical delay discounting questions. From each participant, we inferred indifference points at each level of delay or effort, and hyperbolic curves were fit to each set of indifference points. Despite exhibiting similar discounting functions and fit indices, delay discounting rates did not correlate significantly with effort discounting rates, suggesting that the two discounting mechanisms do not share the same psychological or biological processes and likely evolved to serve distinct purposes. Further, times spent looking at the different alternatives and decision reaction times increased as effort levels increased but were unrelated to delay length. A greater portion of time was spent looking at the chosen effortful reward than the chosen delayed reward, though not chosen alternatives were neglected similarly in both tasks, suggesting that participants not only favored the chosen option more strongly, but also were more attentive when choosing the effortful reward than when choosing the delayed reward. In light of the differences in discounting rates and looking and response time effects, we conclude that delay discounting and cognitive effort discounting mostly likely operate through similar, but distinct decision making mechanisms which engage different levels of attention and consideration.

1-B-10 Genetic neurobehavioral differential susceptibility in valuation and foraging behavior: Insights from DRD4 field evidence in line with VmPFC/ACC dopamine mechanisms and agent-based model in the food domain

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Studies have shown that human can alternate between two modes of economic choice, i.e., valuation and foraging, with distinct neural mechanisms involving dopamine: in the ventromedial prefrontal cortex (VmPFC) comparing economic value of well-defined options, and the anterior cingulate cortex (ACC) encoding the average value of rewards and costs of foraging environments to impact the decision to engage or disengage prior to proceeding to option-specific comparative process. We first develop a canonical model of choice that accommodate both modes and propose that genetic neurobehavioral differential susceptibility to context, that has been shown with individual differences in dopamine signalling, will manifest for both valuation and foraging components, with modulation of prevailing influence on outcome being tied to by the choice context characteristics, i.e., local option-specific (high vs low intensity in-store displays of ice cream or vegetables) vs global patch-like spatial (ratio of healthy/ obesogenic food outlets). We report results of a cross-sectional field study with a sample of 6-12y children for whom (1) dopamine signaling was indexed by single-gene difference on DRD4 7-repeat; (2) individually-defined geo-referenced commercial food environment was characterized in both option-specific and spatial characteristics; (3) outcomes were assessed at both behavioral (healthy/obesogenic) eating pattern and biological (BMI) level. DRD4*E interaction was found for both environment types, with effects observed only for 7-repeat(7R) carriers: valuation-like results pattern observed for eating behavior (7R carriers having more obesogenic eating pattern under high-intensity in store display of ice cream and healthy eating patterns under high-intensity in store display of vegetable). No effect was observed on BMI. For spatial environment, a foraging-like result pattern emerged on BMI (no overall effect on eating) with 7-R carrier reporting higher BMI in healthy compared to obesogenic environment, with this effect being more intense when combined with high-intensity ice-cream in-store display in the healthy environment. We then develop an agent-based model (ABM) of valuation decision making in the eating that accommodate individual and spatio-temporal context heterogeneity. We expand by accommodating both valuation and foraging behavior choice components and we validate this model with children from the MAVAN birth cohort recruited from the same geographic location with

longitudinal outcome measures as well as with a set of neurobehavioral tests and neuroimaging. Theoretical and policy contribution and limitation as well as future research are discussed

1-B-11 Simultaneous tracking of expressed and encoded opioid subjective reward value

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Substance use disorders, including opioid use disorder, have been characterized as decision-making pathologies (Kalivas and Volkow, 2005), implicating decision-making processes as a potentially important target for the development of therapeutics. However, preclinical choice models of opioid abuse often fail to model certain aspects of a user's natural environment, including the relative probability of reward outcomes (both opioid and non-drug) and any reward-associated cues that likely modulate the relative reward value of each alternative. Thus, the current experiment used a preclinical rat model to assess the updating of relative value for a remifentanil (remi) reward alternative at various doses (1, 3, and 10 µg/kg) vs. a food reward alternative while varying the reward outcome probabilities of both alternatives unpredictably. Reinforcement learning models (RLM; e.g., Rutledge et al., 2009) suggest that the value of choice alternatives is continually updated via reward prediction error signals, and changes in NAc neuronal firing in animals (e.g., Sugam et al., 2012) and blood oxygen-level dependent (BOLD) signal in people (e.g., Rutledge et al., 2010) have been demonstrated to be correlated with changes in these value signals. To maximize translational fidelity with BOLD studies, we used RLMs and simultaneous measures of nucleus accumbens (NAc) oxygen use via amperometric electrochemical detection (Ledo et al., 2017), a measure highly correlated with BOLD (Lowry et al., 2010). Two groups of rats engaged in probabilistic decisions between remi and food that also differed in drug-associated cues. For the Unsignaled group, choices of remi or food both led to the presentation of different uninformative cues followed by either reward or reward omission. For the Signaled group, food reward was signaled as in the Unsignaled group, but when a remi choice resulted in reward, an informative cue always preceded while a different informative cue always preceded a reward omission. RLM successfully parameterized choice data and indicated remi choices were strongly dose-dependent for the Unsignaled group. However, the Signaled rats placed greater weighting on informative remi wins that were less dependent on the reward dose. O2 measures were also dose-dependently modulated, showed differentiation between win and loss trials, and the time course of O2 changes across trials depended on the presence or absence of the informative cue. The results suggest that stimuli informative of reward enhance the value of associated alternatives and may be a critical component of why individuals continue to choose drug rewards.

1-B-12 Eye-tracking and computational modelling reveal novel insights into altruistic choice under time pressure.

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Why are some people generous and others, selfish? Research on altruistic choice has often revolved around whether human beings are intuitively and automatically pro-social or if self-control is required to override selfish impulses. The available research using time pressure to answer this question yields contradictory results, with some reporting increases in pro-sociality and others reporting decreases. Recently developed computational models provide an alternative account (Hutcherson et al, 2015) and indicate that, beyond changes in preferences, choice outcomes could depend on other factors. To disentangle these possibilities, we applied computational model-fitting to a series of four studies manipulating time pressure within dictator game paradigms. In studies 1 & 2, we found little overall change in generosity under time pressure. Computational modelling also showed little change in preferences and only disproportionate increase in noise. However, further analyses revealed consistent

and systematic individual differences in the effects of time pressure on altruistic choice; selfish individuals became more selfish while generous individuals became more generous. We hypothesised that time pressure may have exacerbated attentional biases during choice. To test this hypothesis, we included eye-tracking in study 3. Results suggested that increased selfishness was associated with biased initial fixations on self-related value-stimuli and that time pressure exaggerated this bias. These findings have important implications in understanding altruistic choice, suggesting that time pressure results in re-prioritization of information gathering, exacerbating individual biases and preferences.

1-B-13 Dorsal anterior cingulate cortex encodes strategy updating in effort-based decision-making

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Integrating cost and benefit information is crucial for optimal decision-making. Prior work has implicated the dorsal anterior cingulate cortex (dACC) as critical for encoding subjective value, choice difficulty, and subjective value prediction errors during cost/benefit decision-making. To date however, it remains unknown how this region uses such processes to create, update, and refine strategies to guide choice behavior and ensure such optimal decision-making. To this end, we recruited participants to complete a sequential effort-based decision-making task while undergoing functional magnetic resonance imaging (fMRI). As part of this task, two runs were manipulated to contain trials with subjective values that were significantly above (high reward) or below (low reward) participants' indifference points. In these runs, participants developed clear choice preferences to either accept or reject the Effort Option, respectively. We observed greater dACC activity when participants chose the option that deviated from their default choice preference, suggesting a role in encoding shifts in choice strategy. This pattern was strongest for low reward trials that fell below participants' indifference points. These results suggest a broader role for dACC to encode deviations and strategy updating in economic decisions. This region and this particular role may prove critical in furthering our understanding of disrupted decision-making so often observed in psychiatric disorders.

1-B-14 Is attention mediating the memory bias in preferential choice?

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Many decisions rely on past experiences. Recent research indicates that people's decisions are biased toward choosing remembered options, even if these options are comparatively unattractive (Gluth, Sommer, Rieskamp, & Büchel, 2015). In the current study, we investigated whether visual attention (fixations) serves as a potential mediator for the memory bias in preferential choice. Our specific hypotheses were that people pay more attention to remembered options and that people prefer options they have looked at longer (Krajbich, Armel, & Rangel, 2010). In our study, N = 37 participants completed a two-session within-subject eye-tracking study. In both sessions, participants learned the association between locations on the screen and various food snacks. After a delay, they made decisions between options that they either saw directly (non-memory-based decisions, NMB) or that they had to retrieve from memory (memory-based decisions, MB). Last, we assessed which options they could remember. The two sessions differed in terms of whether participants saw both options simultaneously or sequentially (i.e., one after the other). Our results indicate that participants did not pay more attention to remembered compared to forgotten options. However, we found that the tendency to choose the last-fixated option was even stronger in MB decisions than in NMB decisions. Furthermore, when presenting options sequentially, participants showed a preference for the second option in MB but not in NMB decisions. Consequently, these two effects may arise from an increased impact of attention on MB decisions, although it does not mediate the memory bias. To predict choices and response times as well

as to describe the interplay of attention, memory, and decision-making we will use the attentional Drift Diffusion Model (aDDM; Krajbich et al., 2010). The aDDM assumes that people consider advantages and disadvantages of the available choice options in a stochastic accumulation-to-bound process. In addition, the aDDM includes a bias in the accumulation process towards the fixated option. We will present behavioral, eye-tracking and computational modeling results and discuss the findings in light of their meaning for everyday decisions. As decisions seem to be biased by memory and attention, integrating those effects in a common framework may help to improve policies that aim to support people to make more adaptive decisions.

C. Individual & Lifespan Differences

1-C-15 To run with the herd or not, electrophysiological dynamics predict preference change in crowdfunding

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The herd instinct is a common feature of human society and is seen in entertainment, fashion, and the adoption of new gadgets. Indeed, social influence, taking account of others' actions in one's decisions, is ubiquitous in our daily life. With the growing prevalence of crowdfunding investments, an increasing number of studies are focused on how social influences impact such behavior. Only a few studies have examined the neural correlates and possible predictors of social influence on the phenomenon of herding especially with regard to crowdfunding. The current study aims to parse the neural processing of social influences on crowdfunding investment and examine whether neural signals can predict an individuals' willingness to invest. Our results demonstrate that the greater ones' choice deviates from the overall group judgement, there is an increased deflection of the feedback related negativity (FRN). However, both the averaged and single trial analysis revealed that, the subsequent P300, rather than the feedback related negativity, reflects the magnitude of social influence on individual behavior. Specifically, single trial analysis of the EEG data revealed that, in addition to the behavioral manipulation, the deflection of the P300 rather than FRN is a valid signal to predict the behavioral adjustment following the group opinion at the trial-by-trial level. The current study extends the growing literature on social influences stemming from anothers' action to crowdfunding investment decision making and suggests that the P300 component at the outcome stage is predictive of the behavioral shift evoked by following the herd.

D. Finance

1-D-16 Effort measured by pupil dilation predicts reappraisal success

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Reappraising emotional events is a key skill for adjusting to life's challenges. Yet to date it is unresolved how to quantify the effort needed for reappraisal and whether it relates to success. Pupil dilation has long been linked to cognitive effort (Kahneman & Beatty 1966), but how much effort drives pupil dilation is hard to quantify as the pupil readout conflates arousal and effort signals. We present a novel effort index based on pupil dilation that significantly predicts reappraisal success. Eye-tracking was recorded from 34 healthy volunteers (mean age: 22.6 ± 2.2 years; 20 w) during a standard reappraisal task. Participants reappraised or viewed positive and negative stimuli from the International Affective Picture Set (IAPS) and rated the elicited feelings. The stimuli presented in reappraisal and viewing blocks in each domain were equated for average arousal based on an IAPS validation by Gruehn and Scheibe (2008). We quantified reappraisal success as difference between reappraisal and view ratings for negative stimuli

(where successful reappraisal results in more positive feelings), and vice versa for positive. We identified a time window between 3.1 and 5.6 seconds after stimulus onset in which the pupil diameter during reappraisal was significantly larger than during viewing affective content (cluster-based t-test, $p < 0.01$). As we had equated the stimuli for arousal and subtracted the signal related to viewing affective content, the remaining pupil dilation signal is a signature of the reappraisal process. We calculated the area under the curve for the average reappraisal pupil time series in this time window in order to quantify the effort an individual invested. We next modelled in a Bayesian linear regression reappraisal success as a function of this pupil effort index and affective distance (i.e., the absolute distance of the view ratings for the reappraised stimuli from neutral, or short: the starting point of regulation). Within-sample, the pupil effort index explained differences in reappraisal success (beta = 0.34 ± 0.14, 95%CI [0.06, 0.61]) above and beyond affective distance (beta = 0.30 ± 0.14, 95%CI [0.02, 0.58]). In a leave-2-out crossvalidation, the model significantly predicted out-of-sample which of the two left-out participants was more successful (accuracy = 61.14%, $p < 0.001$). In sum, our method allows unobtrusively quantifying the effort that individuals have to invest to regulate. Our results also show that individuals who try harder are more successful in modulating their emotions. Acknowledgements: We gratefully acknowledge funding through EU FP7 Grant 607310 (SUM), and the Richard Büchner Foundation (MG).

1-D-17 Cross-validation of measures of arousal and emotion as responses to natural scenes: Self-report, facial expression analysis, pupil size, skin conductance, and inter-beat interval

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Objectives: Due to widespread decreases in the cost of neurophysiological measurement devices and user-friendly software, there has recently been a resurgence of interest in measures of arousal and emotion, such as facial expression analysis (FEA), pupil diameter (PD), skin conductance (GSR), and heart inter-beat interval (IBI). The objective of this research is to cross-validate these measures for human responses to natural visual stimuli. Methods: Subjects viewed a random sequence of control/target pairs of natural scenes (12 emotional, 10 neutral). Each target picture was in view for 6 seconds and was preceded by a matched control that was in view for 3, 4, or 6 seconds. Each control was constructed from its target by randomly relocating grid elements (100 pixels x 100 pixels) into a mosaic that did not form a natural scene but retained the global and local distributions of luminance in the target. While viewing these stimuli, PD, GSR, IBI, and facial expressions were recorded. Facial expressions were subsequently analyzed by two FEA algorithms (Affectiva and Emotient). After viewing the stimulus stream, subjects completed a survey in which they chose the verbal label that best represented their reaction to the picture (afraid, angry, disgust, sad, neutral, and happy) and rated their reaction on scales of intensity and valence. For each stimulus pair time intervals were defined as Control (0 to 3 seconds prior target onset), Early (0 to 1 second after target onset; E), Middle (1-3 seconds; M) and Late (4-6 seconds; L). Data were analyzed using ANOVA, with subject as a random effect and Time Interval and Stimulus Pair as fixed effects. The effects of interest were computed as linear contrasts for each target time interval compared to the control interval. A separate ANOVA was conducted for each emotion label. Results: For PD, negative effects were observed for Afraid (M, L), Angry (M, L, positive for E), Sad (E, L), and Happy (M, L); positive effects were observed for Disgust (E, M) and Neutral (M, L). For GSR, negative effects were observed for Angry (E, L, positive for M); positive effects were observed for Afraid (L), Sad (M, L), and Neutral (L). For IBI, negative effects were observed for Afraid (E), Angry (E, M, L), Sad (E, M), Neutral (E, M), and Happy (E, M); positive effects were observed for Afraid (L) and Sad (L). Both FEA algorithms captured emotional valence well for Angry, Happy, and Neutral (which was positive). However, there was frequent disagreement for the other verbal categories. Conclusions: Although the

pattern of results was complex, cross-validation was highest for emotional valence and mixed for arousal.

1-D-18 The emotional marketplace: If money could buy love and happiness, how much would people pay for it?

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People spend billions of dollars every year to experience specific emotions--buying tickets for roller coaster rides to feel excitement, exotic vacation getaways to feel relaxed, or for insurance to reduce anxiety. Like money, emotion is a representation of value, offers utility to the consumer, has costs and benefits, and serves as a common currency in judgments and decisions. While research has examined the influence of emotions on economic decision making, little research has examined the economics of emotional experience. Given that people are motivated not by money itself, but by the underlying value it represents, and almost all satisfaction comes from emotional experiences, in a series of studies we investigated the monetary value of specific positive and negative emotional experiences. In three studies of healthy adults between the ages of 21 and 80 (N=1174, N=300, N=104), people reported the highest Willingness to Pay (WTP) to experience joy/happiness and love and reported the highest WTP to avoid sadness and loneliness. For studies 1 and 2, the 95% confidence intervals for WTP for love and joy/ happiness were higher than and did not overlap with any other positive emotions (e.g., contentment, sexual desire, strength, hope, gratitude, compassion, determination, amusement, alertness, enthusiasm, pride, restfulness, awe, euphoria) indicating that these emotions were more highly valued than the rest, $p < .001$. There was more overlap of the WTP confidence intervals for avoidance of negative emotions (e.g., WTP was also relatively high for avoidance of fear/anxiety). In a fourth study (N=121) we examined the emotions that are experienced by the items on which adults spend money in their everyday lives each month as a measure of whether real-world spending maximizes emotional utility. The emotions most frequently associated with monthly spending were joy/happiness (n=242), gratitude (n=165), and contentment (n=161). This series of studies are the first of which we are aware to attempt to estimate the monetary value of emotional experiences. An important limitation of the data collected thus far is that it was almost entirely based on self-reports. In ongoing work, we are collecting objective measures of consumer spending across various categories to verify whether these experimental results generalize. As yet, there is no known measurement for emotional utility or emotional currency. We hope that these studies offer insight into how different economic measures can be used to assess affective value and allow for comparisons between how individuals "spend" monetary and affective resources.

1-D-19 The neural basis of ambiguous unfairness in the Ultimatum Game

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Previous studies using the Ultimatum Game (UG) have shown a clear distinction between highly unfair offers (10-20% of the total amount) that are predominantly rejected and moderately unfair offers (30-40% of the total amount) that are characterized by a vast heterogeneity in rejection rates. This heterogeneity reflects higher ambiguity and increased context-sensitivity. The present study aims to examine the neural mechanisms that underlie the processing of these ambiguous offers. Forty healthy subjects were presented with offers that are characterized by different level of unfairness (i.e. 10, 20, 30, 40, or 50% of the total amount) while functional images of their brain were acquired. Highly unfair offers were predominantly rejected (65-75%) while rejection rates in ambiguous offers were very low (3-20%). Interestingly, responses to ambiguous offers were significantly slower than highly unfair or fair offers. Contrasting highly unfair and ambiguous offers to fair offers (50%) revealed the expected pattern of

increased activation in bilateral anterior insula, dorsal anterior cingulate cortex and pre-supplementary area (SMA) suggesting that both types of offers are perceived as unfair. However, ambiguous offers evoked additional activation in dorsolateral PFC and bilateral inferior parietal gyri. Direct comparison of ambiguous with highly unfair offers revealed increased activation in visual cortex areas, inferior parietal gyrus, dorsolateral PFC, pre-SMA, and putamen. The differential brain activation pattern in response to these two types of offers cannot be attributed to the difference in rejection rates since both accepted and rejected trials displayed this pattern. Taken together, the behavioral and neuroimaging findings suggest that there is a shift from an intuitive and emotional response during highly unfair offers to more deliberate and cognitively demanding processing of ambiguous offers. Ambiguity during fairness-related decisions triggers the recruitment of cognitive control areas that may facilitate the integration of information regarding the cost and benefits of different actions, personal goals, past experience, and context-specific factors like frames. The integration of this information leads to more adaptive decision-making in the face of uncertainty.

1-D-20 The influence of anger on strategic cooperative interactions

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Research on the influence of negative discrete emotions on strategic outputs is a captivating yet still nascent area in the neuro-behavioural sciences. In this multi-study project, we focus on the investigation of the causal effect of anger on performance and cooperative interactions, whose direction and mechanisms have been toilsome to decipher thus far. First, by performing a between-subjects laboratory experiment, we induce anger in participants (N= 62; 6,509 data points) playing an indefinite repeated Prisoner's Dilemma game against each other, and show resulting decline in both performance and individual profits. We further disentangle behavioural evidence suggesting that anger-induced subjects use suboptimal strategies compared to the control group. Second, we confirm and extend these findings by performing an online between-subjects experiment on an independent sample of subjects playing the same game against a computer playing with pre-imposed strategies mimicking those revealed in the laboratory study (N= 76; 4,333 data points). Third, we shed a light on the mechanisms of autonomic emotional regulation induced by anger by analysing participants' linear and non-linear heart rate variability (HRV) indexes. Our results indicate that subjects exposed to anger induction, while engaged in the game, experienced a considerable depression of linear and nonlinear HRV biomarkers associated to their vagal tone. This evidence allows to infer that in presence of anger one's nervous system regulates the timing and magnitude of a subject's emotional responses through vagal modulation, in turn eliciting emotional suppression. This mechanism makes anger-induced players perform more slowly and with less complex strategies than those in the control condition. Altogether, our research advances theoretical and practical implications regarding the impact of discrete negative emotions on strategic outcomes.

E. Consumer Behavior & Marketing

F. Intertemporal Decision-Making & Self-Control

1-F-21 Identifying the computational role of the TPJ for strategic social interactions

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Objective: Competition is ubiquitous in social settings. Strategic interactions require tracking of rewards as well as predicting the opponent's actions and updating higher-order beliefs ("what does my opponent think I will do?"). Previous work has demonstrated that predicting opponent beliefs causally depends on

activity in the temporoparietal junction (TPJ). However, it is unclear whether TPJ involvement is triggered by social context (belief that one faces another human) or by computational demands of interacting with any reactive process. In this study, we sought to tease apart these two competing accounts. Methods: We used a game requiring subjects in the fMRI scanner (N = 60) to guess on each trial which of two cards was selected by the opponent. Two different groups of subjects played this game in either a social (matching pennies against a presumed human opponent) or a non-social (guessing a draw from a card deck) context. In both contexts, subjects actually alternated between facing two computer opponents: one that reacted to the subject's actions according to a reactive algorithm and one that generated a noisy sequence. This allowed us to test whether TPJ activity reflects social context or the nature of the predictive computations. Results: The behavioral data were best explained by a learning model that continuously arbitrates between a sequence-learner and an influence-learner via prediction error-based updating. Neurally, BOLD activity in the right TPJ was modulated by the social context, reflecting the opponent type in the non-social condition and reward in the social condition. Moreover, the TPJ activity reflected sequence prediction error, generated by the computational model, but only in the non-social case. Conclusions: Our results suggest that the TPJ's involvement in strategic behavior might not reflect functional specialization for social interactions per se, but rather computations that detect and deal with interactive processes. Acknowledgements: This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 725355).

1-F-22 The interaction of visual attention and cognitive reflection in interactive games

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OBJECTIVE In social contexts, we refer to strategic sophistication as the ability to adapt our own behavior based on the possible actions of others. Growing experimental evidence has shown that agents often deviate from normative responses in interactive games, and non-equilibrium models have been introduced to explain players' behavior in terms of hierarchical levels of strategic thinking. Moreover, several studies have linked strategic choices to game representation processes and cognitive reflection, which expresses the tendency to implement either rich or poor information processing. Nonetheless, the cognitive mechanisms underlying strategic behavior are far from being understood. In the current study, we tested the hypothesis that the interplay between game representation processes and cognitive reflection could explain the heterogeneity observed in game playing. METHOD In two eye-tracking experiments, we registered eye movements of participants while playing matrix games of increasing relational complexity (2 x 2 and 3 x 3 matrices). Moreover, participants in both experiments completed the Cognitive Reflection Test (CRT). In games, we analyzed patterns of information acquisition to identify the types of payoff comparison performed by participants and thus to understand the type of game representation they were building. Then we tested whether relevant patterns of information acquisition in games were modulated by CRT score, and whether this interaction explained behavior heterogeneity in strategic choices. RESULTS Results show that, in both classes of games, strategic choices were explained by the ability to incorporate the counterpart's incentives in the model of the current game. Such ability was predicted by the CRT score, and completely mediated the relationship between cognitive reflection and strategic behavior. High CRT players anticipated others' actions, incorporating information about other's incentives in their model of the environment, and indeed chose strategically. Conversely, low CRT players analyzed game matrices disregarding relevant comparisons between others' payoffs, and this incomplete visual analysis led to non-strategic choices. CONCLUSION Our results

provide novel evidence for the interplay between general abilities in information processing and game representation mechanisms, revealing their crucial role in explaining strategic interaction.

G. Game Theory & Strategic Interactions

1-G-23 A large-scale comparison of raw cognitive task measures versus derived model parameters for individual difference analyses

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Objective: Forced choice tasks are widespread in cognitive psychology. They yield raw measures (RMs: response time (RT), accuracy) that have been criticized for speed accuracy trade-off and interpretive difficulty (Pachella 1974; Wickelgren 1977). Researchers therefore often compute contrasts of RMs that isolate a putative cognitive process (e.g. Stroop effect is the RT and accuracy cost on incongruent compared to congruent trials) and implement computational model that link cognitive processes with latent parameters (e.g. drift-diffusion models, DDMs). As Hedge et al. (2017) keenly highlight, measures from these tasks become established due to their low between-subjects variance (e.g., the Stroop effect is a 'good measure' because it is robust and similar across participants). Yet this low between-subject variability also leads to low reliability, making them unsuitable as individual difference metrics. In a large sample of cognitive tasks related to self-regulation, we compared the reliability and predictive validity of RM, contrasts, and model parameters. Methods: 150 MTurk participants completed 14 forced choice tasks twice (average delay = 111 days). In addition to raw DVs we computed contrasts and fit two types of DDMs yielding 274 measures. We compared the retest reliability and predictive validity of these DVs with respect to smoking behavior, alcohol use, financial decisions and mental health, "real-world" measures that putatively relate to self-regulation. Results: Model parameters (MPs) have moderate reliability and were comparable to RMs for non-contrast measures (NCMs) (M = 0.6, SD=0.18). Contrast measures (CMs) were less reliable than measures that used all the trials from a task or a condition (b=-0.36, t(266)=-15.27), as expected from the compounding of variances through subtraction. Contrasts based upon both raw measures and model parameters had low to no reliability (M=0.245, SD=0.242), bringing into question their use as individual difference measures. MPs and RMs had similar predictive validity (b = -0.0004, t(3192) = -1.02. CMs had lower predictive validity than NCMs (b = -0.001, t(3192)=-2.98). However, predictive validity was low: none of the measures explained more than 1% of the variance. Conclusions: We found that contrasts had both low reliability and low predictive validity. Therefore, though contrasts may be effective tools to isolate cognitive processes, they are particularly poor individual difference measures. These results hold important implications for measures that Neuroeconomics borrows from cognitive psychology especially when associating them with real-world decisions.

1-G-24 Nucleus accumbens response to stimulant cues predicts relapse

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Addiction to stimulants (e.g., cocaine, methamphetamine) has been hypothesized to involve enhanced neural responses in the mesolimbic circuit to drug cues, as well as diminished responses to conventional reward cues. Such a reallocation of neural evaluative responses to drug versus conventional reward cues may encourage relapse. We combined a drug cue task with functional magnetic resonance imaging (FMRI) in a longitudinal study of detoxified patients with a stimulant use disorder (n=36) and healthy control subjects (n=40) to test whether stimulant use disorder is characterized by distorted mesolimbic responses to drug versus conventional reward cues, and whether these responses would predict relapse.

Our analyses focused on three predicted regions which colocalize with mesolimbic dopamine projections: medial prefrontal cortex (mPFC), nucleus accumbens (NAcc), and ventral tegmental area (VTA). Relative to controls, patients showed evidence of sensitized neural reward responses to drug cues in all three regions. Patients also exhibited blunted responses to conventional reward (food) cues in NAcc, but not mPFC or VTA. Further, patients' increased NAcc responses to drug cues specifically predicted relapse months later, above and beyond predictions afforded by self-report and clinical measures. Relapse classification based on NAcc responses to drug cues performed as well as classification based on whole-brain activity, further suggesting that activity in this region uniquely supports neural processing that perpetuates stimulant dependence. If neural responses to drug cues predict and promote relapse, neuroimaging methods may confer added value in helping clinicians to identify individuals at greatest risk for relapse to stimulant use.

1-G-25 Gaze pattern and pupil size reveal the mechanisms underlying loss averse decisions

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Loss aversion is the common tendency to avoid losses over acquiring equivalent gains. People will typically accept a 50-50 chance to win or lose a certain amount of money only when the gain is nearly twice as much as the loss. Most studies, however, implicitly assume that the decision is instantaneously made and that all individuals perform the task in the same way. However, the decision-making process can be continuous and deliberative, especially when offers are closely matched in value. It is possible that people actually visually scan the offers before eventually accepting or rejecting the gamble, a hypothesis we tested here. Moreover, an anxious person may routinely reject the gambles--making rejection a habitual response for him/her. If this is true, we reasoned that the threshold to accept the gamble would be higher, require more effort and take longer. To understand the decision process, we monitored gaze while participants performed a gambling task. To determine response difficulty, we measured response times and pupil size. Sixty two participants, recruited via the Wharton Behavior Lab, enrolled in the study. The experiment consisted of two blocks of 100 trials each. Each trial was sampled from a gain/loss matrix ranging from ±$1 to ±$10 in increments of $1. At the end of the session, one trial was randomly selected and a payment made according to the actual decision. Participants received a $10 endowment in cash at the beginning to offset potential losses during the session. Consistent with our hypotheses, gaze patterns and response times varied systematically with offer values and reflected loss aversion as estimated by Prospect Theory. Viewing the gain option for longer tended to increase the chances of accepting the gamble, suggesting that gaze patterns influence the decision process. Moreover, people who were highly loss averse took much longer to accept gambles, and showed increased pupil dilation when making these decisions. Overall, the difference in accept and reject response times, and pupil size for accept and reject decisions, increased with increasing loss aversion. To quantify the relationship between gaze patterns and loss aversion, we adapted the attentional drift diffusion model (aDDM) -- an accumulation-to-bound framework for decision-making biased by the locus of attention. The aDDM showed that the decision-making process is influenced by the gaze fixations, and that accept thresholds are higher for people who are high loss averse. In summary, we find that gaze and arousal are key biomarkers for loss averse decisions and suggest they may have potential utility for identifying anxiety disorders from financial behavior.

H. Learning & Memory

1-H-27 Assessing temporal relationships on an internally simulated timeline of the future

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Introduction: Imagine you need to catch a bus. You have some estimate of when the bus will arrive at the nearest bus stop, and some estimate of how long it will take for you to walk to that bus stop. In order to catch the bus, you need to make a decision in the present based on the future temporal coincidence of two events: when you will arrive at the bus stop, and when the bus will arrive at the bus stop. We created a task in which participants had to base decisions on the anticipated temporal coincidence of future events. Successful performance would signify that people can make judgments about the projected overlap of future events on a mental timeline. Methods: Participants (n = 8) were instructed to make temporal judgments about the future. They were first trained on a repeating probabilistic sequence of 15 letters. On each test trial, the sequence was interrupted with a two-alternative forced-choice probe. Participants were rewarded for choosing the probe item that was more likely to occur in the sequence within a bounded future time window (4 to 6 items after the probe). Accurate predictions yielded 15 cent rewards. Each probe consisted of a target, which was likely to occur within the window, and a lure, which was likely to occur either earlier or later (2, 3, 7, or 8 items after the probe). Results: 6 of 8 participants performed above chance ($p < 0.05$) in the final test block; performance ranged from 70%-80% for these participants; the other 2 participants performed near chance. Response time (RT) scaled sublinearly with the lag to the more imminent probe item, consistent with previous results in the domains of both prospection and memory. Some trials repeated the same probe at the same point in the sequence, and the correct response could therefore have been directly reinforced; however, accuracy was no different on these potentially reinforced trials. Conclusions: Our results suggest decision makers can flexibly represent multiple anticipated future events on a projected mental timeline. Successful task performance required 1) a temporal estimate of the future letters in the sequence, 2) a temporal estimate of the bounded future time window, and 3) some means to compare the two and identify their temporal alignment. Performance was not attributable to reinforcement learning, nor could it be explained by simple heuristics; participants could not be successful by systematically choosing the more- or less-imminent probe item. The sublinear relationship between RT and lag to the more imminent probe is consistent with the hypothesis that prospection involves the ability to scan along a compressed timeline of the future.

1-H-28 Impaired calibration of voluntary persistence in depression and attempted suicide

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Background: Behavioral withdrawal in depression is traditionally understood as a manifestation of low vigor or impaired reward learning, and may also involve underestimating the cost of inaction or waiting. Suicidal behavior in depression is further associated with impulsivity, preference for immediate relief, and suboptimal choices under uncertainty. Nothing is known, however, about how people vulnerable to suicide deal with uncertain future rewards. We addressed this question in a behavioral study of voluntary persistence in depression and attempted suicide. Methods: Following detailed clinical, psychological and cognitive characterization, 209 people with major depression (87 suicide attempters, 59 suicide ideators, and 63 non-suicidal depressed individuals) and 68 non-psychiatric controls completed the Willingness to Wait voluntary temporal persistence task (McGuire & Kable, 2012), involving repeated opportunities to wait for temporally uncertain rewards. It was configured so a limited degree of persistence was advantageous (up to 3 s on each trial), but persistence through longer delays (up to 20 s) was counterproductive. We examined differences across the four groups in (1) willingness to initiate waiting for the larger delayed reward in preference to a smaller immediate alternative, and (2) ability to curtail persistence at the appropriate time if the larger reward had not yet arrived. Results:

Relative to non-psychiatric controls, the three depressed groups displayed a tendency toward over-persistence, suggesting insensitivity to the temporal statistics of rewards and/or to the opportunity cost of waiting. The depressed groups exhibited less flexibility in balancing the strategies of waiting and quitting (Kruskal-Wallis c2 = 9.1, p = 0.03). Suicide attempters were differentiated from the other groups by their reactivity to recent outcomes; relative to other participants, they were more likely to forego waiting altogether on trial t if they had given up on waiting for the larger reward on trial t-1 (c2 = 19.7, p = .0002). This difference remained significant after controlling for impulsivity, intelligence, cognitive control performance, and comorbid psychiatric conditions. Conclusion: Depression was associated with a pathological over-persistence while waiting for delayed rewards, consistent with strategic inflexibility and insensitivity to opportunity costs. History of attempting suicide was associated with an over-reactivity to recent outcomes, manifesting in avoidance of waiting. The results add to our understanding of how low-level abnormalities in adaptive decision-making contribute to psychopathology.

1-H-29 Intertemporal choice is affected by attribute range.

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Intertemporal choice tasks typically require participants to choose between options that vary on two attributes: amount and delay. The range of each attribute may impact discounting by making the higher variance attribute more salient. As an initial test of this, we gave 226 subjects on mTurk 80 trials of an intertemporal choice task, including several preregistered manipulations and predictions (https://osf.io/tyhva/). For some participants, delay was constant across trials and amount varied, while for other participants amount was constant across trials and delay varied. Other factors that differed between participants included whether real or hypothetical money was used. The analysis included 163 subjects, after removing 13 subjects according to preregistered criteria and an additional 50 subjects who did not show evidence of a consistent discount rate according to a post-hoc threshold. In line with our pre-registered hypothesis, a Bayesian hierarchical logistic regression showed the odds of choosing LargerLater over SmallerSooner in the "delay varied" condition were 74% of those in the "amount varied" condition (95% CI=[68%, 81%]), controlling for covariates including the calculated indifference point based on a hyperbolic discounting computational model used to determine the task amounts and delays. We also found that the odds of choosing LargerLater over SmallerSooner in the "Small, Real" condition were 20% higher than those in the "Large, Hypothetical" condition (95% CI=[1%, 45%]). Our finding suggests that sensitivity to reward differs based on the range of delay and amount across trials, possibly mediated by the impact of range on attribute salience. In an ongoing fMRI follow-up study (preregistered at https://osf.io/zrfgh/), we examine within-subjects whether the above effect is enhanced after overnight fast (and reduced after acute glucose consumption). We predict that subjects in metabolic deprivation will have an enhancement of the general tendency to focus on the attribute that varies across trials. Thus fasting will be associated with steeper delay discounting when delay (but not amount) varies across trials, but diminished delay discounting (i.e., more patient decisions) when amount (but not delay) varies across trials. We will present available findings from this ongoing study.
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1-H-30 What do laboratory measures of self-control in the monetary domain tell us about self-control for healthy and unhealthy food rewards?

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Ability to exercise self-control is predictive of favourable outcomes in many domains: people with higher self-control achieve higher levels of education, are healthier, have lower BMI, and are less likely to be in

debt. To remain healthy, people must exercise self-control to forego the immediate pleasure of high-calorie foods for the prospect of future health. Self-control is not just choosing delayed rewards, but also persisting in this choice until the delayed reward arrives (Kable, 2014). We use a longitudinal design to measure teenagers' and young adults' self-control for three reward types: money, healthy food, and unhealthy food. Our focus is on adolescents and young adults, because eating habits, established early on in life, tend to stay with individuals later in their lives, contributing to the obesity epidemic (Sahoo et al., 2015). To date, 27 subjects (data collection in progress) participated in our longitudinal experiment. Participants came to the university three times, always on the same weekday and at the same time of the day. The first two sessions were one week apart, and the third session was delayed by further two weeks. In week 1, subjects chose what quantity of reward to receive in week 2 and week 4 (both rewards delayed). In week 2, the same subjects chose from the same options except that their decisions were between an immediate reward ("Today") and a delayed one ("In two weeks"). We employed a modified version of the Convex Time Budget design (Andreoni and Sprenger, 2012) with 12 choice sets differing in the interest rate at which the sooner and later rewards were traded. Our design also allowed us to quantify participants' irrationality for each reward as the number and severity of Generalised Axiom of Revealed Preference violations. We included three reward types: money, healthy and unhealthy foods. The healthy options were popcorn, almonds, or raisins; and the unhealthy options were Cheezels, M&Ms, or gummies. At the beginning of each session, each participant chose their preferred unhealthy and healthy food that served as the reward in the experiment. For each participant, we measured their BMI and hunger levels. Participants made highly rational choices for each reward type. Across all rewards, as the interest rate increased, the percentage of rewards allocated to the sooner date decreased. We find differences in self-control estimates for different rewards. Our results provide evidence on the predictive power of self-control measures obtained with monetary rewards for food choices. We relate self-control measures of each reward type to BMI and hunger levels.

I. Valuation & Value Systems

1-I-31 The effects of evidence accumulation on incidental memory

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Exploring our environment provides information that facilitates adaptive choices. Often, this exploration involves sampling external information until a decision-maker has enough evidence to commit to a choice. Previous research has characterized how people navigate this search process, including how various personality traits, mental illnesses, and neuromodulators affect information gathering. However, how the process of evidence accumulation shapes our later memory for sampled information and events remains poorly understood. Because evidence accumulation can be a costly and lengthy, it would be advantageous to remember parts of the decision process to help guide later choices. Our study therefore sought to understand how differential strategies of information gathering influence later memory. We collected behavioral and eye-tracking data from 105 participants using a modified version of the Information Sampling Task (Clark et al., 2005). In the original version of this task, participants sampled discrete pieces of information that belonged to one of two categories (i.e. shapes of different colors) until they felt confident they could identify which category held the majority inside a box. Here, information was conveyed via trial-unique images that could be grouped into two categories (i.e. indoor and outdoor scenes). Participants completed trials in which they could win a small ($1.00) or large reward ($5.00) if they answered correctly. Participants incurred a sampling cost for each image sampled. Twenty-four hours after completion of the sampling procedure, participants returned to the lab for a surprise memory test. Behavioral performance was compared to an optimal stopping model that

maximized expected value. We classified participants based on how often they either over-, under- or optimally-sampled. Over sampling and optimally sampling lead to increased accuracy ($r = 0.65$, $p < 0.001$; $r = 0.22$, $p = 0.02$), while undersampling lead to decreased accuracy ($r = -0.71$, $p < 0.001$). However, over-sampling was correlated with decreases in later memory ($r = -0.42$, $p < 0.001$). Further analyses will begin to unpack on a trial-by-trial level how the features of the sampling environment could predict subsequent memory. Understanding how and why individual pieces of information seen during evidence accumulation processes are encoded and consolidated may provide insight into how the brain prioritizes specific parts of search processes. Insight into this mechanism would allow us to elucidate how people learn from past decisions that involve prolonged active search and characterize how episodic memory informs adaptive search processes.

1-I-32 The value of choice facilitates subsequent memory with age

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Objective: Control over one's environment is crucial for optimizing outcomes, and has myriad effects on cognition. In this study, we expand upon a recent finding that perceived agency enhances memory in adults. We are interested in how the mnemonic benefit of agency develops, and whether it depends upon the utility of agency in a given context. Methods: The present study tested children (ages 8-12), teenagers (ages 13-17), and adults (ages 18-25) in a within-subjects paradigm where we manipulated whether subjects had capacity for control over their environments. We framed the task as a space exploration game to engage our younger participants. On each trial, subjects visited one of three galaxies with the goal of finding treasure. Half the time subjects had agency and could choose which of two planets in the galaxy to visit; in the other half, subjects lacked agency and the planet was chosen for them. The utility of agency varied by context. In one galaxy, the probability of finding treasure was equal for both planets. Thus, having agency was inconsequential. In the other two galaxies, treasure was more frequent in one planet and so having agency in those contexts had utility. Each time a planet is visited, the subject finds an object and learns if it is trash or treasure. We tested recognition memory for those objects after a 24-hour delay. Preliminary Results: All age groups learned to consistently choose the planets with high reward probability. We found that children had better memory (greater d-prime) for the objects overall than adults, but they were not influenced by agency. The mnemonic benefit of agency increased linearly over development, but only in contexts for which agency had utility. Conclusion: We replicated and extended a previous finding that adult memory benefits from agency during encoding. However, this benefit only occurred in contexts where the ability to make choices was meaningful, suggesting sensitivity to the value of agency. Furthermore, the mnemonic benefit of agency emerged over development. This highlights the importance of examining how learning mechanisms evolve with age. When presented with identical contexts, individuals can learn differently depending on their cognitive and neural development.

1-I-33 Strategic encoding of useful information across development

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Objective: Previous work has revealed that individuals show enhanced memory for information associated with explicit value signals at the time of learning. However, in the real world, such explicit signals are often absent. Instead, the value of remembering information depends on the structure of the environment. In this experiment, we examined whether individuals could infer the value of remembering information based on the frequency with which such information would be needed in the future and strategically modulate encoding accordingly. Additionally, we examined how the cognitive mechanisms

underlying strategic memory encoding change across development. Methods: We collected data from 30 adults (18 - 25 years old) as they completed two blocks of three separate tasks. Data collection in children and adolescents (7 - 17 years old) is ongoing. In each block, participants learned the frequency with which they would encounter different items - either once or five times - and the total number of points they could earn by remembering information about them (1 or 5, respectively). Then, participants learned information associated with each item. Critically, participants viewed information about each item once, regardless of the frequency with which they saw it before. Participants were informed that they would earn one point for every item for which they could remember the associated information. In this way, the frequency of each item signaled the value of remembering information about it. Finally, participants completed a memory test for the associations and for the item's original frequency. For example, in one block, participants viewed different postcards, which repeated either once or five times. They then saw a unique stamp associated with each of the unique postcards, after which their memory for the postcard-stamp pairs was probed. Results: At test, adults were able to distinguish the high- and low- frequency items, $t(39) = 8.7$, $p < .001$. Most relevant to our question of interest, adults demonstrated enhanced memory for information associated with higher-frequency items, $\chi^2(1) = 16.0$, $p < .001$. While adults' memory performance improved across blocks, $\chi^2(1) = 9.0$, $p = .003$, they did not show improvement in selectivity for the high- vs. low- frequency pairs ($p = .35$). Conclusions: Our results indicate that adults are capable of inferring the value of information from the statistics of their environment and then using this learned information to prioritize memory for high-value information. Ongoing work will probe developmental changes in both the learning of environmental statistics and the use of this information to modulate memory encoding.

1-I-34 Learning from reward feedback in high-dimensional environments

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Learning from reward feedback can become extremely challenging in high-dimensional environments with myriad choice options each with many features (curse of dimensionality), as it is the case in the real world. One solution for the curse of dimensionality is to learn reward values of individual features and combine these values to estimate reward values for each option (feature-based learning) instead of learning the value of individual options directly (object-based learning). We have hypothesized that this feature-based learning occurs not just because it can reduce dimensionality, but more importantly because it is faster and therefore more adaptable. Based on this hypothesis, we have recently proposed a framework for learning in high-dimensional environments for which we provided some experimental evidence (Farashahi et al., 2017). This framework also predicts that if the environment is stable (reward values associated with different options do not change very often), the decision maker may gradually learn the reward values of conjunctions of features as a compromise between fast but less accurate feature-based learning and slow but more accurate object-based learning. Here, we tested this prediction in an experiment in which human subjects selected between pairs of visual targets (27 objects defined by three visual features: color, pattern, and shape) and received binary reward feedback on every trial. The reward probability on a given option was determined by the combination of all features whereas one "informative" feature and the conjunctions of the other two "uninformative" features could predict reward probabilities to some extent. We found that majority of subjects learned the informative feature first before learning about the conjunctions of the uninformative features. This was reflected in choice behavior (as revealed by fitting of subject's choices) as well as estimates of reward probabilities. Interestingly, we also found that subjects who only learned individual feature values attributed reward outcomes to the informative feature at the expense of non-informative features. Specifically, these

subjects increased (decreased) their tendency to choose objects that shared the same informative features as the rewarded (unrewarded) objects on the previous trial but did the opposite for the non-informative features. Overall, these results suggest that learning about conjunctions of features and competitive associations of reward to individual features (e.g. via attentional selection) can provide plausible mechanisms for adaptive learning in high-dimensional environments.

1-I-35 Rational (in)attention in observational learning

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Objective. We test an idea that the success of observational learning depends not only on the prowess of the demonstrator, but also on the time when her behavior is observed. In situations where it is costly to discover a good strategy, the timing of observation can influence the way information is treated. If the choice of a knowledgeable demonstrator, which brings high payoff, is available before the decision is made, it can be optimal to simply follow the advice without paying the cost of understanding why this choice is good, as this already guarantees high payoff today. When the choice of the demonstrator is revealed only after the decision, an investment into learning is worthwhile as it increases the payoffs in the future. Presenting information about a good choice before the decision leads to rational inattention to the reasons behind such choice, whereas presenting this information after the decision stimulates learning. Methods. In phase 1 of the experiment, 322 participants play 22 different 3x3 one-shot normal form games against a computer that uses level 1 strategy (best response to the belief that the opponent is uniformly randomizing among her three actions). In phase 2 of the BEFORE treatment, participants face the same games against the same computer, but, before making their choices, they observe the actions that a participant, who scored the most in phase 1, has chosen. In phase 2 of the AFTER treatment, participants observe the action of the highest scorer only after they make their choice. In phase 3 of both treatments participants play 22 similar games without observation. Results. We measure how well each participant is performing in each phase by the percentage of level 2 choices (best response to level 1). In phase 1 of both treatments the average percentage of level 2 choices is the same (52%). In phase 3, though, we find a significant difference between the two treatments: 64% in the BEFORE treatment versus 70% in the AFTER treatment (ranksum p=0.03). This supports our hypothesis that in the BEFORE treatment participants do not try to understand why a knowledgeable demonstrator made her choice, whereas in the AFTER treatment they choose to do so. This is consistent with a model in which rational agents with heterogeneous abilities choose whether to pay a cost of learning from observation or ignore the meaning of provided information. Conclusion. Observational learning can be inefficient when information about a good choice is readily available. This promotes copying and discourages learning at the expense of future earnings. Providing this information after the decision facilitates learning and increases future payoffs.

J. Choice & Choice Mechanisms

1-J-36 Stealing a win: Social influences on risk taking correlate with theft

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Objectives: We sought to quantify the effects of direct social interaction on risk preferences and link that measure to real-world risk taking. Social factors are the strongest predictors of engaging in risky behaviors like drug use. Previous work has shown that the presence of peers can increase risk taking but these effects are indirect, not requiring interaction. We sought to develop a real-time interactive version of the balloon analogue risk task (BART) in which social modulation of risk preferences and their neural

correlates could be measured and related to real-world risk taking. Methods: Participants were recruited in groups of 4-10 (1 of whom underwent fMRI) to play competitive version of the BART task, providing large behavioral samples (n=156) and fMRI data. In this competitive game, participants played a random opponent whose identity was hidden, allowing them to only utilize information from the immediate interaction. Post-experiment, standard economic measures of risk and ambiguity preferences, and surveys of real-world risk taking behaviors were administered. To insure the BART could be related to standard models of risk, participants first observed balloons popping placed a series of bets on when another balloon would pop (providing a belief distribution and subjective measure of risk). Results: Pumping behavior on cashed balloons showed participants were, on average, mildly risk averse. Participants' behavior on individual trials were coupled to the behavior of their opponent. Compared to playing alone, players would cash in after more pumps if their opponent pumped to a high level and after fewer pumps when their opponent's balloon popped early. We determined the slope of this effect for each participant and used it as a measure of their susceptibility to social influence during risk taking. While behavior while playing alone correlates with drug use, this social-risk susceptibility measure correlates with the likelihood that a participant has stolen something in the last year ($p<0.01$). A finding that survives Bonferroni correction and replicates in a second, independent sample. FMRI activation specifically to risk taking in the competitive task correlates with activity in the temporal-parietal junction (TPJ) but not other areas of the brain associated with risk. Conclusions: We found that susceptibility to direct social influence on risk preferences correlated with stealing and was related to activation in the TPJ but not in areas of the brain previously associated with risky decisions. This is consistent with the domain specific view of risk, in which social risk is processed in areas of the brain related to social processing

1-J-37 Acute stress exposure yields no effect on risk or ambiguity preferences in the loss or gain domain

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Objective: Although stress exposure is an inevitable part of daily life where decisions that involve non-certain outcomes are often made, reports of stress effects on such decisions are equivocal across the literature. One potential reason for this is because the majority of this research has focused on risky decisions, for which outcome probabilities are explicitly known. However, decisions are often made under conditions of ambiguity, for which outcome probabilities are unknown. Here, we test whether dissociating risk and ambiguity might allow us to identify whether stress selectively alters decisions with known versus unknown outcome probabilities. Method: We conducted two independent studies using an incentive-compatible experimental economic paradigm that dissociates attitudes toward risk and ambiguity. In both studies, healthy participants first completed the decision task under non-stressed conditions. A week later, participants returned and were randomly assigned to repeat the decision task after a validated acute stress induction technique (Cold Pressor Task) or matched control task. Saliva was collected throughout each session to assay cortisol and alpha-amylase levels--two neuroendocrine markers of stress responses. Study 1 (n=58) was tested in the gain domain (240 binary choices between a certain gain of $5 and a lottery where they could win $0 or a larger amount of money). Study 2 (n=55) was tested in the loss domain (240 binary choices between a certain loss of $5 and a lottery where they could lose $0 or a larger amount of money). Critically, the probability of the gain or loss was either stated explicitly (i.e., risk) or with some degree of ambiguity (Levy et al., 2010). Results: In both studies, subjective and neuroendocrine measures of stress response were elevated in the stress group during session 2 only (when stress levels were manipulated), confirming the efficacy of our stress induction

technique. In Study 1 (gain domain), individuals' choice behavior--as measured by the proportion of risky or ambiguous lotteries selected during the choice task--did not change across sessions for either the stress or control condition. Further, choice behavior did not differ between conditions after stress responses were manipulated during session 2. In Study 2 (loss domain), all participants demonstrated increased risk aversion across sessions, but this did not differ by stress condition. As in Study 1, choice behavior did not differ between stress conditions during session 2. Conclusions: Our findings suggest that exposure to an acute stressor does not influence risk or ambiguity preferences in neither the gain nor loss domain.

1-J-38 The effect of ambiguity on treatment choices across four physician specialties

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Objective: Physicians typically make treatment choices under high levels of uncertainty. In some cases, the likelihoods for potential treatment outcomes can be estimated ("risk"), but in most cases, these likelihoods are not precisely known ("ambiguity"). Previous research has shown that ambiguity substantially affects decisions in various domains, and that most individuals forego large ambiguous rewards in favor of smaller, unambiguous ones (Ellsberg 1961). This study investigated the effect of ambiguity on hypothetical treatment decisions among physicians. We hypothesized that on average, physicians will exhibit ambiguity aversion. We also examined how the physician's specialty, and the patient's age and gender, affect these decisions. Method: 315 specialists (cardiologists, neurologists, oncologists, and rheumatologists) reviewed medical scenarios about a hypothetical patient with a life-threatening condition. The gender (male/female) and the age (young/old) of the patient varied across participants. The participant then made a series of choices between novel treatment options. In each choice situation, one option would guarantee a slight improvement in which the patient survives but is severely impaired. The other treatment option could lead either to a better outcome for the patient (moderate, major or full recovery), or to death. In half of the trials, the probability of the improved outcome was precisely stated (25%, 50%, or 75%). In the other half, part of the information about outcome probability was hidden, rendering this probability partly ambiguous. Results: Consistent with our hypothesis, physicians across all specialties exhibited ambiguity aversion ($M = -0.18$, $SD = 0.25$, $t(222) = -11.0$, $p < 0.001$). Contrary to our hypothesis, however, there was no significant differences among specialties ($F(3,219) = 1.48$, $p = 0.22$). Similarly, patient age and gender did not affect treatment choices (age: $F(1,311) = 0.69$, $p = 0.46$; gender: $F(1,311) = 0.03$, $p = 0.87$; age x gender: $F(1,311) = 0.33$, $p = 0.57$). Conclusions: Our findings reveal that, similar to the general population, physicians are affected by ambiguity when choosing treatments for their patients, preferring treatments with known outcome probabilities to treatments that offer better outcomes, but at unknown probabilities. Despite differences in training and clinical experience, however, physicians across specialties we examined exhibit similar degrees of ambiguity aversion. In addition, ambiguity aversion in our study does not seem to be systematically impacted by the age or gender of the patient.

1-J-39 A circuit-level model of reward learning under uncertainty

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Though neural correlates of expected uncertainty have been found in many species' brains, we still do not know how these signals contribute to or are influenced by volatility in the environment. To accurately estimate volatility of the environment, or how rapidly reward conditions change, decision-makers should take into account estimates of outcome probabilities. However, most normative models of learning under uncertainty assume a hierarchical representation of expected and unexpected

uncertainty (volatility) in which the estimation of volatility is independent of estimates of outcome probabilities. Similarly, it is unclear how volatility could influence learning in reinforcement learning models that update reward values based on reward prediction error. Thus, none of the predominant models of value-based learning provides plausible neural mechanisms for or testable predictions about how the computations of expected uncertainty and volatility are performed, and importantly, how they interact with each other. We have recently shown that reward-dependent metaplasticity provides a plausible mechanism for both computation of value under uncertainty and the estimation of volatility. Here we propose a circuit-level model for computation of expected and unexpected uncertainty and how the two interact. The model consists of three areas; two areas that estimate reward probabilities using plastic and metaplastic synapses, and one area that estimates volatility based on the output of metaplastic synapses. Volatility is estimated using the output of the metaplastic system on a trial-by-trial basis. This signal is then sent back to both plastic and metaplastic systems to make them more adaptable when volatility is high. Based on previous findings, we hypothesized that anterior cingulate cortex (ACC) and striatum compute reward probabilities using metaplastic and plastic synapses, respectively, whereas volatility is computed in basolateral amygdala (BLA). First, we show that feedback using the volatility signal in BLA, based on input from ACC but not striatum, can improve performance in probabilistic reversal learning. Moreover, we show that inhibition of connections from ACC to BLA reduces learning more strongly than inhibition of BLA to ACC connections. Overall, our circuit-level model proposes a plausible mechanism for interactions between computations of expected and unexpected uncertainty. In addition, it provides specific testable predictions about the contributions of different areas and their connections to learning and choice under uncertainty.

1-J-40 The risky brain: Local morphometry and degree centrality as neural markers of psychometrically-derived risk preference factors

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The neural functional correlates of risk-related processes have been mapped extensively, but much less is known about the extent to which neural structure contributes to individual differences in risk preference. Given the life time impact of some decisions made under risk, gaining a better understanding of the biological underpinnings of individual differences in risk taking is a worthwhile endeavor which may hold some insights for longitudinal and developmental research designs that target neural markers. To overcome some of the shortcomings of previous studies, including the use of single indices for both risk preference and neural structure, we combine multi-modal imaging with psychometrically-derived risk preference factors in the imaging sub-sample (N=131 young adults) of the Basel-Berlin Risk Study. We focus our analyses on volumetric and connectivity indices for a set of neural regions identified by Neurosynth-facilitated meta-analytical procedures as core correlates of the term 'risk'. To quantify the robustness of the contribution of individual structural indices, we complement traditional multiple regression analyses with Bayesian model comparison and selection. Our results suggest that structural indices account for close to 16 percent of variance in a general risk preference factor, but are not predictive of domain-specific risk preferences. At the level of individual predictors, our results are mixed with regards to providing a conceptual replication of previous studies: While our findings support the role of striatal and frontal grey matter volume and amygdala connectivity for individual differences in risk preference, we did not find significant brain-behavior associations that are based on grey matter volume in amygdala, insula and posterior parietal cortex. We discuss our findings in light of the suggestion that

the general risk preference factor captures the trait dimension of risk taking. Moreover, we address potential reasons for the observed absence of previously established brain-behavior associations, including the idea that some risk-taking measures differentiate between individuals primarily as a function of cognitive processes relevant to risky choice (e.g., numerical ability). Our study highlights the benefit derived from multi-modal imaging for our understanding of the biological basis of individual differences in risk preference, as well as the measure-dependent nature of many established associations between neural structure and risk preference.

K. Social Rewards & Social Preferences

1-K-41 Choosing for another: Social context changes computational mechanisms of risky decision-making

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Extant research on risky decision-making demonstrates that on average people are both averse to risks and to incurring losses. However, real world choices often occur within rich social contexts, with consequences both for ourselves and for others, including people we are close to and those we barely know. While recent work suggests that people alter their behavior after observing patterns of others' risky choices, it is unclear how the identity of the recipient of an outcome (i.e., self, stranger, friend) influences risky choice. We adapted an economic risky decision-making task to include two manipulations of social context. Participants received a monetary endowment of $24 to use in this task. Across 3 rounds, (90 choices each, 270 choices total), participants chose between gambles (50% chance of receiving a positive or negative/zero outcome) and guaranteed options (100% chance of receiving $0 or a small positive outcome), in which the recipient of monetary outcomes changed. In the first round, participants chose for themselves (self). In rounds two and three (order counterbalanced across participants), choices were made either for another person (other) or in which outcomes were shared between the participant and another person (both). We also manipulated partner identity: one group made (n=23) choices with a same-sex stranger and another group (n=18) made choices with a same-sex close friend. A generalized linear mixed-effects logistic regression modeling effects of choice options (i.e., gamble outcome amounts/guaranteed amount), social presence (self/other), outcome recipient (other only/both), and partner identity (stranger/friend) on choices revealed reduced rates of risky choice in the presence of another person ($p<.0001$). This pattern was exacerbated when outcomes were shared versus for another person only ($p<.001$), more so when partnered with a friend versus a stranger ($p<.02$). A hierarchical Bayesian estimation procedure (Stan) further characterized how computations underlying risk evaluation were altered (i.e., risk attitudes, loss aversion, choice consistency): participants were more risk averse [95% CI: -.17, -.08], more loss averse [95% CI: .02, .13], and more consistent [95% CI: . 30, .55] in their choices in the presence of another. In sum, our results indicate that the tendency to make a risky choice is subject to both value-independent and value-dependent effects of social context. These findings suggest that the depth of the social world is mirrored in its nuanced consequences for our choices-we take into account not just whether our choices affect ourselves or someone else, but the closeness of our relationship to that person.

1-K-42 Influences of social psychopathology on social valuation and behavior

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Objective: Although various psychopathologies have been associated with deviations from typical social behavior, the cognitive processes mediating those differences are not well understood. Here, we

integrate approaches from behavioral economics, social psychology, and clinical psychology to investigate how three psychopathologies relate to core aspects of social functioning: how people perceive others (social perception), how people treat others (social behavior), and the influence of social perception on treatment. Method: We collected self-report data from 990 participants (ages 19-88) on scales representing a range of psychopathologies (the autism spectrum, psychopathy, and social anxiety). Participants also played a dictator game (DG) in which they allocated resources across themselves and members of different social groups (e.g., "Nationality: Russian"; "Occupation: Nurse") and rated the counterparts' warmth and competence. We integrated social perception information into a computational model of inequity aversion. Results: Psychopathology was associated with deviations from typical patterns of social perception and behavior. Severity of all psychopathologies was associated with decreased warmth perception, however only psychopathy and the autism quotient were associated with decreased competence perception. In the DG, those scoring high on psychopathy gave less than average to others and showed increased preferences for advantageous inequity (getting more than others). Those scoring high on social anxiety showed an increased preference for disadvantageous inequity (getting less than others). The autism spectrum showed no overall relationship to equity preferences. Psychopathology was also associated with deviations from the typical use of social perception information to guide behavior. Under advantageous inequity, those scoring high on psychopathy or the autism spectrum were more likely than average to base their decisions on counterparts' warmth, while only those scoring high on psychopathy were more likely to base their decision on competence. Under disadvantageous inequity, all three psychopathologies were associated with lower than average reliance on counterparts' warmth; psychopathy and the autism spectrum were associated with an exaggerated reliance on competence. Conclusions: These findings join recent efforts to identify common dimensions underlying multiple psychopathologies. In particular, rather than producing uniform shifts in social perception and/or behavior (seeing everyone as less warm; giving less to everyone) psychopathology amplified or diminished sensitivity to social perception information during social behavior.

1-K-43 Cognitive and neural mechanisms of exerting social influence

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Research on social influence has mainly focused on the target of influence (e.g., consumer, voter), while the cognitive and neurobiological underpinnings of the source of the influence (e.g., spin doctor, financial adviser) remain unexplored. Here, we introduce a 3-sided Advising Game consisting of a client and two advisers. Advisers managed their influence over the client strategically by modulating the confidence of their advice depending on their level of influence (i.e. which adviser had the client's attention) and their relative merit (i.e. which adviser was more accurate). Moreover, we found that exerting social influence has an intrinsic value, as participants were willing to forego some of their endowment to increase the probability of being chosen as advisers by the client. Functional magnetic resonance imaging showed that the sources of social information which affected behaviour, relative merit and client selection, were computed in distinct cortical regions: relative merit prediction error was tracked in the medial-prefrontal cortex and selection by client in the right temporoparietal junction. Trial-by-trial changes in both sources of social information modulated the activity in the ventral striatum. These results open a fresh avenue for exploration of human interactions and provide new insights on the neurobiology involved when we try to influence others. References: 1. Hertz, U. et al. Neural computations underpinning the strategic management of influence in advice giving. Nat. Commun. 8, 2191 (2017). 2. Hertz, U. and Bahrami B. Intrinsic Value of Social Influence over Others. PsyArXiv (2018).

1-K-44 Modulation of social conformity and confirmation bias with transcranial direct current stimulation: a preliminary study

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When people are facing opinions different from their own, they often change their behaviors to conform to group norms, which is known as social conformity. In addition, when individuals are dealing with social information, especially emotionally-consequential negative information, they have a tendency to search or utilize evidence which is congruent with one's existing belief, which is known as confirmation bias. There is increasing evidence suggesting that social influences affect our behavior via the medial frontal cortex (MFC) (Izuma, 2013; Stallen & Sanfey, 2015). In the current study, we implement an experimental setup in which participants underwent a non-invasive Transcranial Direct Current Stimulation (tDCS), followed by charitable decision-making tasks designed to induce social conformity. We further investigate how the tDCS simulation over the MFC would modulate confirmation bias. In a double-blinded randomization between-group design, 82 participants received anodal, cathodal and sham tDCS followed by a two-session donation task. For the first session, at the beginning of each trial, participants were presented a logo and a mission statement of each organization. They were asked to indicate how much they would like to donate to the organization on a scale ranging from 1 ($0.5) to 8 ($4) within 4 s. Finally, they were informed the average donation by 200 other university students obtained from a previous study (peer-group rating). In an unexpected second session, participants were asked to go through the same procedure once again, in a new randomized order, but without the feedback about the group rating. We demonstrated that compared with cathodal tDCS stimulation, anodal tDCS over the MFC tended to increase overall conformity. Moreover, "stingy" individuals, as compared to "generous" individuals, exhibit a bias in behavioral adjustment towards feedback that was congruent with their prior self- definitions while discounting counterevidence and anodal tDCS enhanced this confirmation bias. Our findings provide evidence for the role of MFC in social conformity and confirmation bias, and the modulatory function of anodal tDCS in increasing such behaviors. Reference Izuma, K. (2013). The neural basis of social influence and attitude change. Current Opinion in Neurobiology, 23(3), 456-462. doi:10.1016/j.conb.2013.03.009 Stallen, M., & Sanfey, A. G. (2015). The neuroscience of social conformity: implications for fundamental and applied research. Frontiers in Neuroscience, 9, 337. doi:10.3389/fnins.2015.00337

1-K-46 Behaviour and neural correlates in an implicit confidence task

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Objective Methods for measuring the confidence with which people make decisions, have traditionally relied on post-decision self-reports. These studies of confidence have found neural correlates of confidence in several areas including rostrolateral prefrontal cortex (De Martino et al., 2013), dorsal and anterior medial prefrontal cortex, bilateral orbitofrontal gyrus, and bilateral striatum (Molenberghs et al., 2016). However, it is not clear if the knowledge of an upcoming confidence report influences the decisions, and/or the neural representation of confidence. In a previous study we have presented a task that can measure implicit decision confidence, and shown that this measure is strongly correlated with an explicitly measured decision confidence. In the present study, participants performed the same task while undergoing functional magnetic resonance imaging (fMRI) scanning to investigate if the neural correlates of implicit confidence differs from those of explicitly measured confidence as identified in previous studies. Methods Thirty-nine participants performed the deceit-free task where they have to move a cursor around a circle to catch particles that move from the centre to the edge of the circle. The

direction of the particles is block-wise determined by a mean and a standard deviation from that mean. The participants can change the size of the cursor, and the amount of points rewarded for each catch is inversely proportional to the size of the cursor. After performing the task in the scanner, participants performed a control task and a Balloon Analogue Risk Task outside the scanner. Results The fMRI analysis showed activation in the expected decision-making areas (including the striatum, thalamus, anterior insula and ventromedial prefrontal cortex) as well as in areas associated with spatial tracking. The analysis also revealed correlation with confidence signals in anterior cingulate cortex and correlation with changes in confidence in anterior premotor cortex as well as both sides of posterior parietal cortex. Conclusion We believe that there is a case for developing methods for measuring confidence implicitly, and our results show that not only could such a task work successfully, but also that the neural correlates might be different from the correlates found in a task measuring confidence explicitly.

1-K-47 Social norms, self-enhancement, and genes; the role of dopaminergic, serotonergic, and oxytocinergic genes in self-construal

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Variation along independent and interdependent self-construal is well documented both within- and across-cultures. Rice theory proposes that, for individuals in Chinese agricultural regions, Northern, wheat-growing regions, are more independent than Southern, rice-growing regions, which are relatively interdependent. In the present study, we investigate neurochemical genetic differences between independence and interdependence. We adopt a novel perspective from social genomics, which conceptualizes cultural acquisition as occurring via coevolution of culture and genes, and conduct an exploratory study to investigate whether genetic pathway genes (e.g., receptor or synthesis genes) coding for neurochemicals involved in three well-defined social reward processing pathways, the dopaminergic, serotonergic, and oxytocinergic pathways, are associated with standard measures of self-construal for Chinese individuals from varying agricultural regions. Five hundred and twelve current students and graduates from universities in Beijing, China were recruited for participation in the study (mean age = 24.22). Of these, 210 were from southern China (109 females) and 302 were from northern China (160 females). Eligible students, who had previously been genotyped as part of a research panel, were contacted via email and completed a one-hour online survey. All participants were of Chinese origin and Chinese was their native language. Each participant was compensated with 100 Chinese Yuan (approx. $15 USD). Principal components analysis was conducted on all independence and interdependence self-construal survey outcomes, and the top 5 components were regressed on eigenSNPs from social reward pathway genes using a minor allele dosage model. Separate regressions for each gene were run using the equation, (1) $\gamma i = \mu + \beta j \chi ij + \varepsilon i$, where γi denotes the survey response of individual i, μ is the mean survey response in the population, χij denotes the minor allele frequency of eigenSNP j for individual i, and εi is the residual or effect of exogenous factors on γi. The slope coefficient for χij, βj, is the unique effect of eigenSNP j on γi. To control for multiple testing, only genes that remain significant at $\alpha = .05$ after a 1000 permutation test are considered significant. Preliminary empirical results indicate that genes involved in social reward pathways are associated with various self-construal outcome measures. Given that self-construal is an important, fundamental determinant of human behavior, understanding the biological components that influence self-construal may provide tangible insights for advancing our understanding of social and economic behavior.

1-K-48 The effect of financial and social incentives on cooperation and its underlying neural mechanisms

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Incentives are frequently used to encourage cooperation. However, most of the literature so far has focused on the effect of incentives administered by peers, such as fellow participants, whereas in society incentives are typically administered by a centralized source, such as a government or an employer. Across two studies, we investigated the effect of centralized incentives on cooperation and its underlying neural mechanisms, examining both financial and social incentives. In Study 1, participants played an adapted version of a Public Goods Game in which incentives were either present or absent. Results showed that both social and financial incentives increased cooperation rates, with financial incentives yielding the strongest effect. In Study 2, we employed the same experimental paradigm while participants underwent functional magnetic resonance imaging (fMRI), replicating the behavioural findings of Study 1. Neuroimaging results of Study 2 revealed an increase in bilateral lateral orbitofrontal cortex and precuneus activity when incentives were absent as compared to when they were present. Furthermore, activity in the medial orbitofrontal cortex was enhanced for social versus financial incentives. These results show that incentives directly impact the neural mechanisms of cooperation. Specifically, social incentives appear to be processed differently than financial incentives, and the presence of incentives impacts the psychological mechanisms underlying cooperation, potentially decreasing the intrinsic motivation to do good.

1-K-49 A neurocomputational account of corruption

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Introduction: Corruption is defined as the abuse of entrusted power for private gains at the expense of others' interest via dishonest conduct. While this topic has been investigated extensively in the past years, its neurocomputational mechanisms remain poorly understood. Hence we performed a behavioral study (N = 28) and an fMRI study (N = 40) by adopting a novel paradigm with computational modeling. Methods: Participants were assigned the role of an arbitrator and informed that an independent online group study had participated in an early study where they played a sender-receiver game. This game consisted of two roles, i.e., a sender and a receiver. Senders played either by themselves (solo context) or with randomly-matched receivers in other cases (dyad context). In the solo context, each sender presented with two options earning themselves different payoffs. In the dyad context, each sender was presented with two options with different payoffs distribution between him-/herself and a receiver. Although senders were requested to always honestly report the option pre-determined by the computer, it was still possible for them to report the alternative options (i.e., telling a lie) to benefit themselves. Importantly, senders could bribe arbitrators at their own cost to persuade the latter to approve their decisions. The task for the participants (arbitrators) was to decide whether to accept the bribe or not. If they accepted it, the sender's decision would be approved, which benefited both the arbitrator and the sender (this also harmed the receiver in the dyad context). Otherwise, the sender's decision would not be approved and neither of the arbitrator nor the sender could earn money (receivers would thus be paid according to the selected option). Results: Behaviorally, participants felt more morally inappropriate to accept and thus more likely to reject the bribe when the sender deceived (vs. honesty) in the dyad (vs. solo) context. Model comparison favors the social preference model including not only the inequity aversion but also the moral concern for probity and victim. At the brain level, value signals presiding (corruptive) choices were encoded in the valuation network (vmPFC, dACC, and PCC). Dishonesty-enhanced value signals in the right AI were modulated by individual difference in probity concern. Moreover, decision-relevant activities were stronger in rostral ACC when the sender deceived (vs. honesty) and such neural difference increased in lateral OFC in the dyad context. Conclusion: Our

findings provided the first characterization of the neurocomputational mechanisms guiding corruptive behaviors.

L. Risk & Uncertainty

1-L-50 Choice-induced value change: evidence for value construction

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Objective: The speed and consistency of decisions between two items depends on the difference in their values, analogous to speed-accuracy regularities in perceptual decision making. We hypothesized that deliberation in preference decisions involve constructive revision of item values, through memory and prospection. If so, such revised values might affect future decisions involving the same items. Methods: Participants first provided willingness-to-pay (WTP) for 60 foods. Pairs were formed such that difference in WTP between two foods varied from trial to trial. Foods appeared multiple times, allowing us to capture dynamics of revaluation. We reasoned that if decisions lead to a change in value, the next time that item appears its value might be updated ±δ (incremented by δ if the item was chosen, decremented if it was rejected). We fit δ for each participant to minimize the deviance of a logistic choice function to the data. The procedure emulates a form of cognitive dissonance, whereby a decision for/against an item increases/decreases its value in subsequent choices. We applied drift diffusion models to explain the choice and RT as a function of ΔValue. We used goodness of fit statistics to determine whether WTP or revised values better explained speed and preference. We used permutation tests, Monte Carlo methods and cross validation to compare models. Results: For all participants (n=30), the DDM fit to the revised values was significantly better than for original WTP (mean ΔBIC=64). Some improvement might be explained artifactually if revealed preferences merely improved the WTP-derived estimates of the (latent) subjective values, but this explanation does not depend on the order of trials in the experiment, whereas the actual improvement did (permutation test), consistent with actual changes in the values of items in the order that they were displayed in the experiment. Were these values revised during deliberation, or were they revised as a consequence of the decision post hoc (e.g. cognitive dissonance)? To address this, we compared a model that used updated values on subsequent trials to one that used the updated value on the trial in which the update occurred. We fixed δ and compared likelihoods of the RT only. The comparison lends greater support to the hypothesis that value is constructed. Conclusions: These findings provide evidence in favor of the hypothesis that the deliberative process during decisions may involve value construction. Such modification of subjective values might help to explain seemingly irrational preferences such as transitivity violation and confirmation bias (e.g. cognitive dissonance).

1-L-51 How do predicted and experienced utilities for food relate to body mass?

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Objective: Overweight and obesity are increasingly prevalent risks for serious health issues and social stigma. It is thus crucial to investigate food choices and food valuation to understand better the physiology of over and normal eating and to potentially inform new treatments for body-fat related disorders. Methods: In this project, we combined fMRI and endocrine analysis methods to explore possible differences in how normal-weight (n=33) and overweight or obese (n=29) women respond to food cues. The two groups completed three tasks designed to measure various components of the experienced and predicted utility of food rewards. These included a taste task, in which they rated the pleasantness and intensity of low and high calorie milkshakes, as well as two tasks measuring the

willingness to pay and to exert effort for food items, respectively. These three tasks were completed four times, i.e. in two menstrual cycle phases (periovulatory or luteal), and levels of satiety (hungry or sated). Here, we focus on effects related to body mass. Results: All participants rated the low calorie milkshake as more pleasant than the high calorie milkshake overall (p=0.019). However, this difference was reduced in high BMI participants compared to low BMI participants (p=0.021). Moreover, participants with an increased risk of weight-related comorbidities, as determined by waist-to-hip circumference ratio, showed less change in milkshake pleasantness ratings between hungry and sated sessions (p=0.016). Interestingly, the trial-to-trial variability in pleasantness ratings increased with BMI (p=0.045), suggesting that the experienced utility of liquid foods is less stable in high BMI individuals. Unexpectedly, measures of predicted utility for food showed a non-linear relationship with BMI. Specifically, the willingness to pay or exert effort for food items decreased for participants at both the low and high ends of the BMI range (range = 19:35; p=0.017 and p=0.015, respectively). Looking separately at the two groups, we found that within the normal weight range, participants were more willing to exert effort or pay more for food items as BMI increased from 19 to 25. In contrast, we saw the opposite pattern for the overweight/ obese group, willingness to pay or exert effort decreases as BMI goes from 30 to 35. Conclusion: Our study reveals body mass-related changes in both the experienced and predicted utility of food. We are in the process of analyzing the fMRI data, with the hope that they will shed light on the neural mechanisms underlying the increased variation in experienced utility and the non-linear relationship between BMI and the predicted utility of food.

1-L-52 fMRI study of non-reinforced behavioral change for faces

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Introduction: The cue-approach training (CAT) procedure was recently introduced as a task to change preferences without external reinforcements or self-control. In the task, the mere association of a cue and a button press response, resulted in preference change. The procedure had been demonstrated for various stimuli and found to have an effect of up to several months. In the current work, we used fMRI to study the neural mechanisms of CAT with faces. Methods: Forty-three healthy participants were scanned with a 3T MRI scanner while performing CAT with faces. Twenty-five of them returned for an additional one-month follow-up scan session. At the beginning of the experiment initial subjective preferences were evaluated for the face stimuli. Participants underwent CAT inside the MRI, during which some of the face images were associated with a cue and a speeded response (Go items), while the other images were not (No-Go items). In the binary-choice probe, participants chose their preferred stimuli from pairs of Go versus No-Go items with similar initial value. In a passive viewing task, we measured BOLD response to the individual stimuli, before and after training. Results: Behaviorally, Go-items were preferred over No-Go items in the probe, both in pairs of initial high-value (prop. = 57.8%, p = 7.3E-5; logistic regression) and low-value (prop. = 55.8%, p = .004), replicating previous studies. In the follow-up session, the reported effects were generally maintained (prop. = 54.8% - 53.1%, p = .09 - .11). Imaging results from the training task, show for the first-time correlations between the behavioral effect across participants and BOLD in the striatum, including nucleus accumbens and putamen. In the passive viewing task, we found a change in the fMRI response following training in occipito-temporal regions. In the probe we found a correlation between the behavioral effect across participants and BOLD activity in ventromedial prefrontal cortex (vmPFC). Response in the 1-month follow-up session indicated an involvement of hippocampus in probe and parietal brain regions in passive viewing tasks. Conclusions: Our results suggest that the neural mechanisms underlying the behavioral change following CAT, involve regions of high-level visual processing, as well as frontal regions (vmPFC), suggesting a modification of

the valuation system via a change of representation in the visual system. Striatal activity during training suggests an involvement of reward processing circuits, even in the absence of external-reinforcements. Parietal and hippocampus activations suggest the implication of attention and memory processes in long-term retention of the effect.

1-L-53 Neural underpinnings of value-guided choice during auction tasks: An eye-fixation related potentials study

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Value-based decision making is concerned with how we choose from several available alternatives based on their subjective value. Using electroencephalographic eye-fixation related potentials (EFRPs), the present study aimed to investigate how neural signals related to value-guided choice evolve over time during an auction task. Participants completed a Becker-DeGroot-Marschak (BDM) auction task involving products priced up to £8 wherein half of stimuli were presented in either a free or forced bid protocol. Stimuli were assigned to three value categories of low, medium and high value based on subjective willingness-to-pay (WTP). Fixations were organised into five 800 ms time-bins encompassing the objects viewing. Independent component analysis (ICA) was applied to the data to identify distinct components representing cognitive processes underlying value-guided choice and independent components were grouped into 18 clusters. Fixation characteristics are also reported to aid EEG and eye-tracking co-registration. Nine of the eighteen clusters passed confidence interval checks. Two ICs were found to represent fixations for high value products with increased activation over the left part of the scalp. An IC covering a frontocentral region of the scalp coded the intermediate values. Finally, one IC displaying activity over the right frontal scalp region responded to low-value items. The component resolving the low-value objects also showed a statistically significant interaction between value and forced-free bids in which low value objects were distinct from other value categories in the forced bid condition only. Only one IC showed statistically significant differences for three value categories over the consecutive 800-ms bins. Results suggest that the subjective value of goods is encoded using sets of brain activation patterns which are tuned to respond to either low, medium, or high values. Each of these sets starts to respond early on during viewing an object and remain active over the entire viewing period. Data indicates that the right frontal region of the brain, possibly the right orbitofrontal cortex, responds to low values, and the left frontal region to high values. These hemisphere differences in encoding low- and high-value items accord with previous studies demonstrating hemisphere differences between positive and negative affective stimuli, such as odours or emotions.

1-L-54 The neural mechanisms of anchoring effects on willingness-to-pay

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Consumers' willingness-to-pay (WTP) for an item is often influenced by prior considerations of purchasing an item for a random price, even when this price is explicitly uninformative to their preferences - an effect termed as anchoring. Despite of its robustness and persistence, it still remains unclear whether anchoring is driven by the process of adjustments from a given anchor or by the process of selective activation of anchor consistent information during valuation. In this study, we seek to answer this question by elucidating the mechanisms underlying the anchoring effect on WTP using fMRI. A total of 27 participants completed the study in exchange for a cash payment (mean age = 25.56, SD = 3.17, 16 females). In each trial, they were presented a market good on the computer screen and asked to answer two questions: (1) whether or not they would be willing to purchase the shown item at

the given price if any (willingness-to-buy; WTB) and (2) the highest amount they would be willing to pay (WTP; ranged from $0 to $100). The trials were classified into three types: WTB the item at a low anchor price ($5~$40), at a high anchor price ($60~$95), or without any anchor price provided (no-anchor). Participants' WTP significantly differed across the three conditions ($F(2, 26) = 34.71$, $p < .001$). Participants were willing to pay more when they considered purchasing items at higher anchor prices than those at low anchor prices (M_{low} = $21.99, SD = 12.33 vs. M_{high} = $29.06, SD = 15.69; $t = 6.22$, $p < .001$), consistent with an anchoring effect. Participants were also willing to pay more (less) when considering to purchase a given item at high (low) anchor price relative to no anchor prices ($M_{no\text{-}anchor}$ = $25.06, SD = 15.54; no-anchor vs. low-anchor: $t = 2.71$, $p = .025$; no-anchor vs. high-anchor: $t = -3.52$, $p = .003$). We found stronger activation in vSTR and vmPFC when participants purchased items during WTB and left anterior insula when they chose not to. Specifically, activity in vSTR was higher when purchasing items at low anchor prices than those at high anchor prices. Critically, vmPFC activity tracked WTP, but only for no anchor trials. For the anchor trials, activity in vmPFC parametrically tracked the difference between WTP and anchor. These findings suggest that the effect of anchoring on WTP is robust and driven by adjustment from given anchor.

1-L-55 Adaptive choice stochasticity is a function of adapting value sensitivity in monkey orbitofrontal cortex

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Variability in decision making can arise from many factors. Noise in the value coding choice architecture, idiosyncratic changing preference, or context dependent value signal representation can lead to stochasticity in simple choice. Here we explore how temporal changes in the composition of available value options influence choice as well as neural sensitivity in monkey orbitofrontal cortex. We propose that mechanisms akin to sensory adaptation - following principles of efficient information coding within finite constraints - influence value encoding of simple options that in turn change choice behavior. We recorded single-unit activity in orbitofrontal cortex (OFC; area 13) while monkeys performed a saccadic choice task between two options differing in reward magnitude and juice type. Blocks of trials comprised a mixture of adaptor and measurement trials. In measurement trials (identical across blocks), monkeys chose between an unvarying reference reward and one of five variable rewards, providing a quantification of probabilistic preference between rewards (a choice curve). Across blocks, we systematically varied the structure of the adaptor trials to induce narrow or wide background reward environments. Overall adaptor variability had a significant effect on both choice behavior and OFC value coding ($p<0.05$). Consistent with an adapting decision mechanism, monkeys exhibited steeper measurement trial choice curves in narrow vs. wide background environments. Of 620 OFC neurons, 288 exhibited a significant ($p<0.05$) modulation by value in the measurement trials (cue or reward period). Consistent with neural adaptation, the strength of value coding was on average stronger in narrow vs. wide blocks ($p<0.05$). Notably, the extent of this coding difference (narrow-wide) corresponded to the behavioral difference in the choice curve slopes (narrow-wide) across sessions. In the cue interval, cells significantly coding value exhibited a strong correlation between neural and behavioral adaptation (M1: $r=0.57$, $p=0.009$, M2: $r=0.39$, $p = 0.035$). Interestingly this correspondence was absent in the reward period. These results indicate a link between choice stochasticity and value coding in OFC neurons, suggesting a neural mechanism for adaptive decision making. Importantly these results also emphasize that choice stochasticity results from value sensitivity in the value encoding architecture and is not simply a result of noise or changing preferences. Current work aims to uncover the extent of this

adaptation on different subtypes of value coding cells as well as model the dynamics of the value adaptation process.

1-L-56 Parsing medial prefrontal cortex: A joint meta-analytic and graph-theoretic approach

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Introduction: Valuation effects are consistently observed in medial prefrontal and posterior cingulate cortex (mPFC and PCC). The spatial extent of these effects is mostly indistinguishable from the default mode network (DMN) in existing meta-analyses. However, little is known about how valuation effects fit within the broader functional architecture of mPFC and PCC, or whether that architecture is consistent or idiosyncratic across individuals. Here we complement a meta-analysis with fMRI-based graph theoretic approaches to subdivide mPFC and PCC at the single-subject level. This is the first in a series of steps geared to produce more refined topographical targets for studies of valuation. Methods: Regions of interest (ROIs) associated with DMN and valuation were identified from meta-analytic data and projected to a standard cortical surface model. Using fMRI data from the Human Connectome Project, we estimated within-subject resting-state functional connectivity among all surface vertices in the ROIs. We then used two separate community detection algorithms to group vertices that were strongly connected with each other and sparsely connected with other clusters. The resulting partitions were evaluated for consistency across methods, throughout individual time series, and across subjects. Results: Valuation and DMN effects had substantial meta-analytic overlap in mPFC and PCC, with the exception of one PCC subregion that was preferentially associated with the DMN. However, the regions of group-level overlap could be reliably segregated into DMN and non-DMN communities in every individual. PCC subdivisions were well aligned across individuals, whereas in mPFC the subdivisions had low inter-individual transferability despite similar qualitative topological features. Using measures from graph theory and mutual information, we found that different community detection algorithms had strong agreement, and that the topographic patterns were fairly stable throughout each subject's fMRI session. The functional subdivisions did not correlate with subject-specific cortical folding, thickness, or myelin density, and were obscured when aggregated across subjects. Conclusions: Our results suggest the functional topography of mPFC has substantial variability across individuals. This highlights the potential usefulness of estimating brain effects at the individual level in this region, and points to limitations of aggregative methods such as coordinate-based meta-analysis in determining whether valuation and DMN effects emerge from common or separable brain systems. Our approach shows promise in addressing this issue through future manipulations of valuation.

1-J-57 Predicting risk attitudes from the precision of mental number representation

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Theories of risky choice assume that individual risk attitudes reflect characteristics of expected utility maximization[1] and/or neural value processing[2]. However, the probabilistic nature of risky choices that is often observed in experimental data could originate from purely perceptual processes. Khaw, Li & Woodford (KLW[3]) elaborate on this idea in a model that formalizes individual risk-attitudes as reflecting only the noisy nature of numerical magnitude encoding, without invoking distortions in expected utilities. The model describes risky choice as arising from optimal Bayesian magnitude coding that gives rise to perceptual biases also evident in numerical cognition. However, it remains unknown whether the model assumptions indeed correspond directly to the underlying perceptual processing of numerical magnitudes. To test this, we asked whether individual risk attitudes can be predicted from the precision (i.e., noisiness) of mental number representations, as derived from an independent numerical cognition

task. In our experiment, we asked subjects to perform two tasks: (a) a simple magnitude comparison between two piles of coins and (b) a risky decision task involving choices between sure and probabilistic lotteries. In (b), the monetary payoffs were represented either as piles of coins (as in (a)) or as numbers. The results of this experiment replicated the original KLW results in showing that psychometric risky-choice curves were logarithmically scale-invariant, consistent with influences of the perceptual encoding of numerical magnitudes. Logarithmic scale invariance held regardless of how monetary payoffs for risky choices were presented, and was also observed in the magnitude comparison task. In line with our hypothesis, individual estimates of perceptual noise inferred from the magnitude comparison task correlated with the noise estimates inferred from the independent risky-choice data, irrespective of whether the monetary payoffs were presented as coins or numbers. Crucially, the precision (or noise) of numerical magnitude encoding measured with the simple magnitude comparison task predicted the individual level of apparent risk aversion. These results suggest that individual risk attitudes may reflect the noise inherent in basic magnitude perception, therefore questioning the validity of standard utility-based models of risk attitudes. More generally, our findings suggest that models of basic perceptual processing may be used to predict complex characteristics of risky choices in different settings. Ref. 1. J von Neumann, O Morgenstern (1944); 2. B de Martino et al Science 313, 684 (2006); 3. M W Khaw et al NBER WP No. 23294 (2017)

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A. Attention

2-A-1 A mechanistic foundation of the role of attention in the framing effect

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Subjective preferences have been shown to change across different contexts even when the options are kept constant. The framing effect is a well documented example of preference reversal in which individuals seem to change their subjective valuation of the options in the choice set. However, the neurological and internal mechanisms that leads people to change their choices depending on the different frames are still unclear. Why should mere changes in the description of an objectively identical relationship between choices and outcomes affect decision-making? Here, we examine the hypothesis that changes in framing cause changes in the allocation of visual-attention to the different options, and in turns visual-attentional changes give rise to changes in the decision process. We document that in decision making under risk the framing of sure alternatives as a gain - as opposed to a loss - induces a visual-attentional advantage for the sure option relative to the risky one which is accompanied with an increase in the choice probability of the sure option, i.e., an increase in risk aversion. Based on an evidence accumulation process (aDDM), we propose an explanation for the framing effect that is exclusively dependent on a reallocation of visual-attention through changes in the parameters of the model that do not involve a changes in the valuation of the options in the choice set. We texted our hypotheses with a hierarchical Bayesian modelling approach (HaDDM), and find that frames have an impact primarily on the initial bias of the evidence accumulation process that, combined with changes in the allocation of visual-attention, can fully explain the observed changes in risk aversion. Our results suggest that the main drivers of framing effects in decision-making are shifts in attention allocation that alter the inner mechanisms of the evidence accumulation process.

B. Emotion & Affect

2-B-2 Exploring the role of orbitofrontal cortex function in drug-related decision-making.

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Drug users do not take drugs in isolation; rather, they are often faced with several concurrently available commodities (e.g. monetary goods, social relationships). Thus, using choice measures to assess the relative subjective value of drug reinforcers in both humans and animals promotes a translational understanding of mechanisms that govern drug-associated decision-making. Additionally, while the orbitofrontal cortex (OFC) has been shown to be involved in value-based decision-making between qualitatively different non-drug alternatives, its role in valuation of drug vs. non-drug alternatives is largely unknown. To better understand the role of the OFC in drug-related decision-making, we used reversible inactivation (baclofen/muscimol microinfusions) and oximetry (a proxy of neuronal activity) in rats performing under a novel cocaine vs. food choice procedure that dissociates preference from intake. Inactivation of the OFC produced a specific decrease in sensitivity to relative cocaine-food magnitude changes, an effect that is consistent with the existing literature implicating OFC function in encoding the relative subjective value of qualitatively different choice alternatives. Further, using a separate group of rats, OFC neuronal activity (as measured by oxygen consumption) was positively correlated with choice, tracked changes in preference with changes in cocaine-food magnitude, but was unrelated to actual reinforcer (food or cocaine) delivery. Thus, we have potentially isolated drug vs. food preference from intake effects due to the fact that OFC activity was specific to choice behavior and associated subjective value. Taken together, these data add to the research suggesting that the OFC is critical for decision-making processes involving qualitatively different goods and extends those results to drug-associated choice mechanisms in substance abuse disorder.

2-B-3 Evidence accumulation and optimal stopping in stochastic economic choice: Challenging the DDM

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Drift-diffusion models (DDM) have had empirical success in fitting both behavior and electrophysiological recordings during binary choice tasks. They model response times along with choice probabilities and permit insights into the processes from which (perceptual or value-based) decisions originate. The recent theoretical literature has shown that the DDM arises as the optimal solution to a constrained set of optimal sequential sampling problems. Sequential sampling problems are a broad class of models that represent the decision maker as accumulating evidence at a time cost, and stopping optimally when this cost exceeds the benefit of acquiring additional information. Each model of this class makes specific assumptions on how evidence accumulates. One particular set of assumptions gives rise to the DDM. Unfortunately, based on choices and response times alone, it is almost impossible to distinguish between different models of this class. We address this problem in a behavioral experiment in which we use a new task to directly measure how choice accuracy evolves with time as evidence accumulates, and compare our findings to choices made under unrestricted time. Our incentive compatible paradigm attempts to, in essence, reveal the evolving decision variable (or "hidden particle") modeled by the DDM in real-time. In each of about 360 trials, subjects are shown 100 "balls", some red and some blue, and are asked whether the majority of these are red or blue. In fixed-time trials the balls are masked after an unpredictable interval that varies between trials (from 0.1 to 6s), and subjects then must select red or blue within 2s of stimulus mask onset. After subjects choose red or blue we elicit their probabilistic beliefs (or "confidence") that their previous choice was correct. Subjects thus report their best guess

(red or blue) and their confidence in that guess. Reaction-time trials, which serve as a control, are identical but of unlimited duration and presented without a mask. As expected and previously demonstrated, the accuracy of choices increases as a function of the time during which the balls are displayed. However, our preliminary results show surprising patterns in how accuracy and confidence evolve with time that appear to be inconsistent with predictions of the DDM. While our results are preliminary, it is surprising that our measurement of the evolving decision variable in an economic task do not accord well with the predictions of the DDM in this task. This experimental methodology thus promises empirical insights that permit to refine bounded accumulation models in a way that is not possible relying on decisions and response times alone.

2-B-4 Linking trial-by-trial variability in computational models to neural data via Leave-One-Trial-Out (LOTO)

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To gain a better understanding of the biological basis of decision making and learning, research in neuroeconomics and decision neuroscience often employ computational models to inform the analysis of neural data. Recently, there has been a growing interest in identifying trial-by-trial variability in parameters of computational models in order to link this variability to brain signals. Yet, previously proposed methods of capturing parameter variability were limited by being restricted to specific models, by being difficult to implement or by requiring a high amount of computation time. Here, we introduce a simple, efficient and general approach to estimating trial-wise changes in latent variables: Leave-One-Trial-Out (LOTO). The basic principle of LOTO is to estimate parameter values of a computational model for the complete dataset and for the dataset with a specific trial being left out. The difference in the estimates is then a reflection of the parameter value in the left-out trial. Using extensive simulations of different models employed in neuroeconomics (e.g., hyperbolic discounting of intertemporal choice; sequential sampling models of decision making), we demonstrate the ability of LOTO to capture true variations in model parameters as well as the neural signals that are associated with these variations. We identify conditions under which LOTO can be expected to provide sufficient statistical power and explain how models and task designs can be adjusted to improve the method's performance. Taken together, the ease, efficiency, and generality of LOTO has the potential to advance research on tracking fluctuations in latent cognitive variables and linking these changes to neural data.

2-B-5 Integrating reinforcement learning and matching theory to understand motivational vigor: A new computational model of free operant learning

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Background: Models of dopamine have noted its role in prediction error-related learning and motivational vigor (McClure el al., 2003; Niv et al., 2006), which may reflect phasic and tonic activity, respectively. In an environment with a high reward rate, individuals may respond more vigorously due to the opportunity cost of not acting to obtain valuable rewards. Vigor often follows a matching law such that response rates are proportionate to corresponding action values (McDowell, 2013). Although theories of matching and motivation have provided descriptive accounts, reinforcement learning (RL) models of free operant learning are less developed. We propose a new RL model that learns the values of alternative actions through experience and scales response vigor accordingly. Methods: The model builds on temporal difference (TD) learning, binning an episode into discrete timesteps. For each timestep, the agent decides whether to respond and which action to choose. Model parameters include

learning rate, vigor sensitivity (coupling of response vigor with average reward rate), basal vigor (probability of response independent of value), motor speed, switch cost, and choice stochasticity. We conducted simulations of two-alternative choice in both stationary and time-varying contingencies, modeling 60 trials lasting 6 seconds each. We further conducted a study of 20 human subjects who completed a two-alternative choice task where both actions had a 20% reward probability. Results: Across simulation conditions, we found a strong correspondence between response rate and the total learned value of actions, avg. r = 0.85. Second, in random walk conditions where reward probabilities varied independently across trials, there was a strong relationship between action-specific response rate and trial-wise subjective value, avg. r = 0.8. Third, response rate for a given action was positively associated with its learned value, avg. $\beta = 0.78$, but negatively associated with the value of the alternative, avg. $\beta = -.26$ (model R2 = 0.72). Fourth, there was a strong log-linear relationship between relative response rates and their corresponding values, consistent with matching theory (avg. model R2 = 0.61). Preliminary analyses of human data revealed a similar log-linear pattern predicted by the computational model. Conclusions: Models of online learning in free operant environments are essential for identifying the latent components of decision-making in realistic environments with opportunity costs. The model proposed here extends established RL algorithms, while providing new insights into the role of value representations in choice and response vigor.

2-B-6 Insulin as a key bridge along the gut brain axis modulation of neurobehavioral processes and real-world behavior: Insights from a field study on neuropsychological performance in 6-12 years old indian children

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Gut-Brain axis (GBA) consists of a bidirectional communication between the central nervous and the enteric systems, linking emotional and cognitive centers of the brain with peripheral body functions. Two of its components are the afferent gut hormonal response pathway (e.g. ghrelin, leptin and insulin) and the neural efferent pathway (Vagus nerve and the autonomic nervous system). Obesity and related diseases are seem as a result of an unbalance GBA, that results in obesogenic behaviors secondary to increased reward sensitivity, unsatisfactory impulse control, and poor judgement and planning, as well as an inadequate feedback control of energy metabolism. Dopamine is involved in much of these critical brain functions and is under the influence of enteric hormones. Insulin plays a critical role in modulating dopamine production, release and uptake in the mesocorticolimbic brain areas, influencing eating behavior, reward sensitivity, and also affects hippocampal functioning by impacting memory through the modulation of synaptic plasticity. Brain insulin resistance reduces brain insulin action, and is believed to be involved in the decrease in neural functions that are seem in aging, diabetes, and obesity. Situations of reduced insulin availability, such as stunting and Intrauterine Growth Restriction, are also associated with the same decrease in executive functions and poor decision making, suggesting it is lack of brain Insulin action that is impacting brain functions and increasing the likelihood of maladaptive behavior. We investigate the mediating effects of insulin on neurobehavioral development in a sample of 612 children of 6-12y from a cohort study in India. We applied a set of neuropsychological tests to evaluate cognition and executive functions (IQ, Semantic Interference (SI), Phonemic Fluency (PF), Working Memory (WM), Visual Attention (VA), Reward Sensitivity(RS) and Cognitive Flexibility(CF) and conducted linear regression using height z-scores as proxy for level of stunting and mediation/moderation analysis for insulin (adjusted for sex, age, SES, maternal age at delivery and height, and number of siblings). Stunting was highly prevalent(27%), and strongly impacted IQ and executive functions except VA and CF. Insulin was

lower in stunted children, and correlated with better performance on VA, WM, and inhibitory control(SI). RS was not associated with stunting nor insulin. Insulin partially mediated the stunting effects on PF. We found a combined effect of stunting and insulin on many, but not all cognitive measurements and propose Insulin as a key mediator between gut and brain processes into determining real world behavior

2-B-7 Efficient encoding of numbers explains biased judgments

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Economic decisions often require the aggregation of multiple sources of information, a simple example of which is the computation of an average (such as the average return on a risky investment). It has been reported that human subjects, when averaging numerical or visual stimuli in comparison tasks, tend to unequally weight different numbers, that should be equally relevant to a correct decision. This selective weighting has been interpreted as resulting from a nonlinear transformation of the presented numbers, that optimally compensates for the presence of internal noise arising later in the decision process.1 A natural alternative hypothesis is that numbers are encoded with noise at the time of their presentation. Under the assumption that this encoding is efficient, the amount of noise should vary in an optimal way across the stimuli space, and the encoding should depend on the prior distribution from which numbers are sampled; neither of these latter predictions have previously been investigated. We design a task in which participants are asked to compare the averages of two series of numbers, each of which are sampled from the same prior distribution. The shape of this prior distribution differs across blocks of trials (it can be either uniform or skewed towards smaller or larger numbers). We show that in addition to a nonlinear transformation, subjects seem to encode the numbers with a degree of noise that varies with the value of the number. In particular, more extreme values (farther away from the prior in either direction) are encoded with greater noise. We further show that this behavior is predicted by a model in which the coding rule maximizes the subject's expected reward under the constraint of a lower bound on the average encoding noise. Our theoretical results predict the way in which the encoding nonlinear transformation and the stimulus-specific degree of noise should depend on the prior distribution. Together, our results both shed new experimental light on the mechanisms by which human subjects process numerical information, and increase theoretical understanding of an encoding-decoding paradigm in which efficient coding is combined with optimal Bayesian inference from noisy internal representations2. 1Spitzer, Waschke, and Summerfield, "Selective overweighting of larger magnitudes during noisy numerical comparison," Nature Human Behavior (2017). 2Wei and Stocker, "A Bayesian observer model constrained by efficient coding can explain 'anti-Bayesian' percepts," Nature Neuroscience (2015); Polania, Woodford, and Ruff, "Efficient Coding of Subjective Value," working paper, 2018.

2-B-8 Goal-directed temporal modulation of probabilistic decision-making: The roles of the VMPFC and hippocampus

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In real-world environments, decision-makers must often integrate behaviorally-relevant sensory information over time and across information sources of varying reliability. To capitalize on transient opportunities for reward, they must also use this information in ways that are contextually-appropriate. To investigate how decision-makers make adjustments in how they integrate and use sensory information, we used fMRI in conjunction with a temporally-extended paradigm, which allowed us to differentiate multiple task epochs within each trial. During the "cue" epoch, participants learned about the timing and magnitude of the rewards available during the impending trial. During the "deliberation"

epoch, participants had to integrate information across time, and across multiple probabilistic features. Importantly, in order to be able to maximize reward, participants had to not only make correct decisions based on the incoming sensory evidence, but also respond when reward was available. Using a model-based approach, we were able to track neural signals reflecting the temporal evolution of cumulative decision evidence and normative decision confidence. We were also able to identify "evidence-independent" signals which reflected the temporal proximity of reward availability. We found that the ventromedial prefrontal cortex (vmPFC), anterior hippocampus (aHPC) and supplementary motor area were particularly sensitive to these temporal demands. Multivariate pattern analysis (MVPA) indicated that the vmPFC additionally tracked the cumulative decision evidence, and that the Fusiform tracked the probabilistic decision evidence provided by each of the individual stimulus features (consistent with known effects of attentional modulation of visual representation). Connectivity analyses indicated that both the vmPFC and aHPC increased connectivity with the Fusiform during deliberation, and that the aHPC additionally increased connectivity with the bilateral intraparietal sulcus and middle frontal gyri. As these effects reflected the temporal proximity of reward availability, the results suggest that the vmPFC and aHPC play important roles in allowing decision-makers to adjust how incoming sensory information is used to make contextually-appropriate choices.

2-B-9 Product vs. packaging decomposing the distinction between perceptual and value-based decisions

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When people shop, they are undoubtedly influenced by both packaging and their mental representations of the products inside the packaging. Therefore, it is important to understand how people make decisions based on both types of information. In the literature, a distinction has been made between perceptual judgments and preference-based decisions, but in our example, choosing based on the item's packaging is both a perceptual- and preference-based task. Accordingly, we argue that the separation of perceptual judgments vs. preference-based choices has thus far been conflated with the separation of decisions based on the stimulus (e.g. choosing which image is larger, based on the image itself) vs. the object represented by the stimulus (e.g. choosing between foods, based on pictures representing the foods). Here, we present an alternative way to categorize decisions, which is based on two dimensions: subjective vs. objective and stimulus vs. representation. We then study the decision-making process in each of the four resulting categories, using the same stimulus set: food images. Specifically, we have subjects (N = 42) first give incentivized ratings for each of the 100 food images in each of the four categories: taste (subjective; representation), weight (objective; representation), attractiveness of the package (subjective; stimulus), and size of the image (objective; stimulus). Then, subjects make 100 incentivized, binary choices in each of the four categories. Subjects are eye-tracked throughout all choices. Overall, we find remarkable similarity across the tasks. Subjects tend to choose the option they look at more (and the option they look at last). However, there are some divisions between the tasks. We see that there is a larger divide between stimulus vs. representation than between subjective vs. objective. Specifically, we see that subjects are most similarly influenced by attention when making decisions about the stimulus (regardless of whether it is an objective or subjective decision). Additionally, machine learning classification methods - which utilize decision process measures, such as attentional influence - most easily confuse the representation tasks, likely due to greater similarity in the magnitude of attention's influence on choice. Ultimately, this provides us with evidence that (1) although attention does play a large role across different choice domains, (2)

preferences for products and preferences for packages may be influenced by attention to different degrees.

2-B-10 The Role of motivational systems in dissecting the neural correlates of ambidextrous decision making

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Ambidextrous managers are good at switching between exploration and exploitation to achieve a balance for maximizing performance. Previous studies have shown that the two managing styles involve distinct decision making behavior. However, very limited is known about how motivational systems affect ambidexterity. Here we tackle this issue by conducting an fMRI study on seventy-six adults while they played 'four-armed bandit' task. General linear model was conducted to model brain activation associated with exploitation and explorations, with the former was defined by participants choosing the bandit with the highest score of the four, whereas the latter referred to the rest of the options. We found that relative to exploration, exploitation behavior engaged strong activations in the striatum, inferior frontal gyrus and superior frontal gyrus in the prefrontal cortex as well as left middle temporal lobe in the temporal cortex. Exploration, in contrast, activated widespread fronto-parietal circuits, including insula, dorsal anterior cingulate cortex, middle frontal gyrus, and posterior parietal cortex. These results suggest that exploitation requires engagement of the neural circuits associating with self-reward system whereas exploration involves a higher-level of cognitive control brain network. Interestingly, when making exploitation decisions, participants' behavioral activation system score was positively correlated with brain activation at Hippocampus but negatively correlated with parietal cortex. In contrast, participants' behavioral inhibition system score was correlated with right insula. Our results have provided novel insights into understanding of motivational systems in ambidextrous decision making.

2-B-11 Predicting memory-based decisions using semantic fluency and preferences

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The past decade has seen substantial progress in our understanding of the neural basis of economic decision-making. Major gaps remain, however, in applying current neuroeconomic frameworks to understand decision-making in the real world. In particular, past studies on economic and consumer decision-making have distinguished between contexts involving "stimulus-based choices" (SB-C) and those involving "memory-based choices" (MB-C). These two contexts differ in that whereas all relevant information is physically present at the time of choice in the former, the latter requires decision-makers to recall what they are seeking in order to find the relevant choice alternatives, e.g. choosing a dinner restaurant purely from memory. Because of the scarcity of neuroeconomic studies on MB-C, little is known about its underlying cognitive and neuro-computational mechanisms. To fill this gap, we develop a computational approach that conceptualizes MB-C as the product of the interaction between processes involving semantic memory (retrieval of eligible items from memory) and preference (valuation of the successfully retrieved items). We collected independent datasets for brands from two consumer goods categories (fast food and running shoes) in order to define three measures: (1) semantic memory, measured by a classic semantic fluency task (i.e. name as many brands in a category as possible; N = 240); (2) valuation, measured by choices in SB-C with a given choice set for a category; N = 1405); and (3) MB-C, measured by choices of brands in a category without a choice set (N = 1405). A direct contrast between MB-C and SB-C revealed notable differences: while some items (e.g. Nike and McDonald's) were chosen much more often in MB-C than in SB-C, some (e.g. Chick-fil-A and New Balance) showed the reverse trend. A quantative examination of our computational models shows that

the "memory + preference" model robustly outperformed models using preference or memory information alone in both categories (Fast food: memory + preference R2=0.937, CI [0.848, 0.965]; preference-only R2=0.455, CI [0.301, 0.566]; memory-only R2=0.803, CI [0.7504, 0.8332]. Running shoes: memory + preference R2=0.993, CI [0.9740, 0.9968]; preference-only R2=0.859, CI [0.804, 0.898]; memory-only R2=0.593, CI [0.534, 0.638]. All CIs are at 95% level). These findings reveal an important cognitive mechanism through which semantic memory influences and constrains value-based decision-making. They also bear important clinical implications for better characterizing suboptimal decision-making in pathological conditions impacting semantic memory, such as Alzheimer's disease and semantic dementia.

C. Individual & Lifespan Differences

2-C-12 Effects of commercial break interruption on EEG frontal alpha asymmetry and program recall rate

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Many neuromarketing studies have examined the effect of TV commercials on psychological processes such as memory and pleasantness. However, little has been studied on interruption by commercial breaks (CBs) even though they can cause negative feelings on TV programs or commercials. The aim of this research is to explore the impact of CB on TV programs and commercials with respect to memory and enjoyment. We performed electroencephalography (EEG) experiments in 51 subjects while they watched two 30-min programs, a drama and a variety show, and twelve 30-sec commercials in total. 26 participants (i.e. CB group) watched the program that was interrupted by CBs twice: one at one-third and the other at two-third of program. Each interruption contained three commercials. The rest of participants (i.e. control group) watched three commercials before and other three after the program. After watching two programs, they were asked to answer the enjoyment level in a 7-scale. About a week later, participants were asked to answer the questions that they had not been informed: enjoyment level for programs, recall of programs and commercials, recognition of programs and commercials, and evaluation of commercials. The result of commercial evaluation showed that twelve commercials were not different with respect to purchase intention, model likeness, and self-assessment of attention indicating that the saliency of commercials were well controlled and that any of them would produce the same amount of feelings of interruption. The CB group exhibited a poorer recall rate for the programs, especially the variety show than the drama, compared to the control group. But no significant difference in the recall rate was found for the commercials. Then, we analyzed EEG data using the power spectral density (PSD) of alpha oscillations (8-12Hz) that was calculated for each one-third segment of the data during viewing the variety show. Alpha power was z- transformed to calculate EEG frontal asymmetry (F3-F4). Two-way mixed repeated measures analysis of variance (ANOVA) was conducted with one within-subject factor, sequences of program (first, middle, last) and the other between-subject factor, experiment group (CB vs. control). A marginal interaction effect was observed, showing increased left frontal activity in the control group only in the last part of the programs. In summary, this study suggests that when TV viewers are interrupted by commercials while watching a program they would feel less pleasant and recall the programs, but not commercials, less accurately.

2-C-13 Consumer privacy tradeoffs: Neural mechanisms underlying privacy calculus

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Consumers are increasingly aware that their information is tracked online, yet may opt to share

information because they receive a benefit, such as loyalty rewards. Although people report privacy is important, they typically disclose more private information than matches their self-reported privacy preferences. This privacy paradox could be better understood by illuminating the psychological processes underlying privacy calculus - weighing the risks against the benefits of disclosure. The present research examines how people integrate information about benefits and risks when deciding whether to disclose private information. In three experiments, we assess the psychological processes shaping privacy decisions and characterize the neural mechanisms underlying these tradeoffs. First, participants (N=37) separately rated the attractiveness of benefits (e.g., "Free shipping") and the intrusiveness of questions (e.g., "What is your Social Security Number?"). After completing these initial ratings, participants then began the privacy decision-making task, in which they viewed a question and a benefit together and rated how willing they would be to answer the question honestly in order to receive the benefit. Analyses regressed participants' willingness to disclose their private information on their previous ratings of the question's intrusiveness and the benefit's attractiveness. The more attractive the benefit was, the more willing participants were to disclose the information, $\beta=0.31$, $p=.001$, while the more intrusive the question was the less willing participants were to disclose the information, $\beta=-0.47$, $p=.001$. Therefore, participants do appear to integrate information about both benefits and risks when deciding whether to share private information online. These findings were replicated in an independent sample (N=68). Participants in Study 3 underwent fMRI while performing the task. Neuroimaging analyses revealed that activation in orbitofrontal cortex and striatum tracked the perceived attractiveness of the benefits. Analyses also revealed that activation in insula, anterior cingulate cortex, and temporoparietal junction tracked the perceived intrusiveness of the questions. Activation in lateral prefrontal and dorsomedial prefrontal cortices integrate these signals to guide disclosure decisions. The present research demonstrates that people integrate information about benefits and risks when considering whether to disclose private information. Clarifying these processes can both address important theoretical issues, such as the emergence of the privacy paradox, and inform interventions to help consumers protect their privacy in online markets.

2-C-14 Brand empathy: Do consumers really care about the fate of companies?

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Marketing theorists have long posited the concept of "brand empathy" to describe consumers' affective resonance with brands. That is, pleasure in response to brands' fortune and distress in response to brands' misfortune. However, to date, no evidence beyond self-report is provided for the existence of brand empathy. Are consumers' reported empathy for brands really reflective of their underlying feeling or just superficial? To address this question, we recorded Apple customers and Samsung customers' neural response to Apple and Samsung's fortune and misfortune in line with their self-report feeling. We primarily focused on two neural networks: the reward network preferentially activated for pleasant feeling, including ventral striatum and orbital frontal cortex, and the pain network preferentially activated for unpleasant feeling, including anterior cingulate cortex and anterior insula. Empathy for brand, if exists, should manifest as activation of the reward network in response to brands' fortune and activation of the pain network in response to brands' misfortune. Apple customers reported empathy for Apple and showed empathic neural response to Apple, i.e., activation of the reward network to Apple's fortune and activation of the pain network to Apple's misfortune. Samsung customers also reported empathy for Samsung, but they didn't show empathic neural response to Samsung. Conversely, they reported envy and schadenfreude toward Apple, and showed envious neural response to Apple, i.e., activation of the pain network to Apple's fortune and activation of the reward network to Apple's

misfortune. Furthermore, regardless of fortune or misfortune, Apple customers showed enhanced activity to Apple relative to Samsung, in ventral medial prefrontal cortex, a region preferentially activated for thought about self vs. other. Samsung customers didn't show enhanced activity to Samsung vs. Apple in ventral medial prefrontal cortex, but showed larger activation to Apple vs. Samsung in dorsal medial prefrontal cortex, a region preferentially activated for thought about other vs. self. Our results suggest that both Apple customers and Samsung customers affectively react to Apple's fate, though in opposite ways. Apple customers think Apple as part of "me" and empathize with Apple, while Samsung customers think Apple as part of "other" and exhibit envy and schadenfreude. Neither Apple customers nor Samsung customers show strong affective reaction to Samsung's fate, though Samsung customers reported concern for Samsung. Our study suggests that neural signature of brand empathy does exist, but it is not universal and it may be beyond the scope of self-report.

2-C-15 Investigation of neural responses to commonly appreciated service-to-service brand extension

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Brand extension refers to the use of established brand names to develop new goods/service. Many marketing researches have shown the importance of a fit between parent brand and new goods/service to the success of brand extension, whereas little is known about cognitive and affective processing of the fit in consumers' mind. Although cognitive neuroscience studies recently investigated consumers' cognitive processes evaluating brand extension, they focused on only goods-related extension. One of the challenging issues in studying service-related brand extension is a large deviation across individuals in terms of personal evaluation of fit levels. To address this, our previous study developed an acceptance rate (AR) by averaging responses to individual stimuli of service-to-service brand extension examples. Using AR, the previous study also investigated cognitive processes during the evaluation of service-related brand extension by analyzing electroencephalography (EEG) and revealed that subjects appeared to evaluate service-to-service brand extension with a more focus on improbability of extension, rather than acceptability of it. However, these results from individual responses could not unveil why a particular extension stimulus was more likely accepted by a group of people. Accordingly, the present study investigated group-wise neural responses to service-to-service brand extension by examining the degree of dominance of fit evaluation over a group of subjects for a particular stimulus. From the AR data, we selected stimuli that received high-/low-fit individual evaluation from more than 85% of subjects. Then, we analyzed group-wise event-related potential (ERP) responses to high- and low-group fit stimuli. As a result, we found several significant differences between the stimulus groups in ERPs after the onset of the presentation of an extension service. In particular, we observed the larger amplitude of P300 elicited by the high-group fit compared to the low-group fit stimuli over left hemisphere. Furthermore, we predicted the fit level of a stimulus from ERP features using a classifier designed based on principal component analysis and support vector machine. The leave-one-subject-out cross-validation showed classification accuracy of 89.47%, indicating a feasibility of predicting whether a given service-to-service extension would be evaluated as high-, or low-fit by a population. The proposed method and the study results may suggest a new neuromarketing tool that can help marketers comprehend group responses to service-to-service brand extension.

D. Finance

2-D-16 Noradrenergic arousal in affective conflict-control

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Efficient mental functioning requires that cognition adequately deals with affective conflict via conflict-control mechanisms. Emotional conflict arises when affective decision-making is hampered due to an interference by task-irrelevant affective salient stimuli. A multitude of affective conflict studies employ the emotional-Stroop task in which participants identify the emotional expression of a face while ignoring an overlaid emotional word, either congruent or incongruent with the facial expression. Critically, congruency effects in this task are subject to sequential modulation in that there is less reaction time interference (i.e., less conflict) for incongruent trials if they are preceded by an incongruent trial (II) than if they are preceded by a congruent trial (CI). It is typically believed, that the conflict generated by an immediately prior incongruent trial activates an 'anticipatory mechanism', which leads to improved conflict resolution on the next trial enhancing conflict-driven adjustments of cognitive control (conflict adaptation). However, the nature of this 'anticipatory mechanisms' is currently unknown. Here we test the hypothesis that the noradrenergic arousal system may drive such preparatory processes and affective conflict-control. Forty-eight participants performed the emotional-Stroop task while functional imaging and pupillometry, a well established measure of noradrenergic arousal, were concurrently acquired. Neural and noradrenergic conflict-adaptation were assessed via contrasting CI > II trials with respect to fMRI-BOLD activity and pupil dilation respectively. Regions previously associated with emotional conflict-adaption, such as Amygdala, dorsolateral- and prefrontal-cortex were replicated. Importantly, a large subcortical cluster involving the locus coeruleus (LC), a region known as the primary source of noradrenergic modulatory projections throughout the brain was also identified. Moreover, pupil dilation prior to incongruent trials was substantially enhance if preceded by an incongruent trial compared to precedence of a congruent trial (pupil conflict-adaptation). Critically the degree of individual pupil conflict-adaptation correlated with the strength of the neural conflict-adaptation responses in the LC. These results are important because they link physiological arousal to emotional conflict-adaptation and suggest a noradrenergic contribution to affective cognitive-control. This work is also clinically relevant as it indicates potential neuro-modulatory avenues towards treatment of psychiatric disorders involving maladaptive emotional conflict adaptation, such as anxiety and depression.

2-D-17 Post-terror affect bluntness: Terror-induced, stressful life events blunted arousal reactivity and impaired affect integration in subsequent aesthetic evaluations

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Stress is a powerful affective modulator that has been shown to influence cognition and decision-making. Using standardized induction procedures, stress research in laboratory settings has suggested time-dependent, opposing effects of acute stress inducing hyper affective responses relative to a slow, long-lasting stress aftermath suppressing the affective systems involved. With an increased frequency of people witnessing terror attacks in our society, it is important to understand how the experience of stressful life events such as terror attacks in one's close surroundings alters emotional reactions and their integration into cognitive processes like decision making. Here, we report results from a unique data set in which a subset of Parisian student participants experienced the terror- related events in Paris and Brussels in 2015-2016 up to seven days prior to their participation. We examined how such a terror-induced stressor influenced participants' affective reactions to winning money and when they made

aesthetic evaluations of pictures using measures of physiological arousal, facial expressions and self-reported feelings. We found that the terror- induced stressor selectively blunted arousal reactivity while leaving the expression of facial valence intact. These results resemble effects of stress aftermath rather than the effects of acute stress, supporting the idea that the slow effects of corticosteroid during the stress aftermath leads to a restoration of pre-frontal cognitive control at the cost of emotional responsiveness causing affective bluntness. Moreover, due to the bluntness of arousal reactivity, the integration of affective reactions due to winning money in the seemingly unrelated subjective evaluation of pictures was also dampened. This result supports a recent arousal transport hypothesis that arousal necessitates carry-over effects of affect on value-based evaluations. Together, our data revealed novel effects of exogenous stressful life events on affect and decision-making in a real-world setting. Our findings may also contribute to illuminating clinical consequences of being exposed to terror attacks by providing new testable hypotheses about why affect bluntness is linked to the development of post-traumatic stress disorder.

2-D-18 Correlation reducer (CoRed): A computational method to transform correlated variables into uncorrelated variables

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The purpose of this paper is to advance the scholarly conversation on construct and statistical conclusion validity in the neuro-behavioral sciences at large, by presenting Correlation Reducer (CoRed). CoRed is a new computational method that allows, without incurring in data loss, to transform correlated linear variables into independent ones which however uphold the associated theoretical constructs' original meaning. Two approaches are used to illustrate this method. First, we mathematically prove and generate the equation set that uniquely satisfies the conditions for correlation reduction. Second, we provide an example of CoRed's application by performing a simulation on a large dataset (N= 1870) in which we disentangle the distinct contributions of affective and cognitive measures on attitude formation. The generalizable conclusions are the reliability of CoRed in ensuring variables' independency and validity departing from correlated variables, and the deriving opportunity to advance research across a wealth of domains by means of a parsimonious computational instrument. Differences with linear reduction methods such as component analyses and avenues for future research are presented; an R package complements this work toward enabling fuller implementation of CoRed.

2-D-19 Apology or explanation: Which one is more effective for redeeming negative online reviews ? based on a fMRI experiment

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Introduction: Both explanation and apology are regarded as effective service recovery strategies to repair customer satisfaction when a vendor receives negative comments, but it remains to be explored which one is better and why it works better. Therefore, this study intends to answer two questions: (1) Which type of response, i.e. apology or explanation, is more effective in redeem the damage caused by negative reviews in online shopping environment? (2)What is the neurophysiological justification of such a result? Here we used functional magnetic resonance imaging (fMRI) to answer the two questions. Methods: fMRI experiment. Nineteen healthy subjects (7 females), between 18 to 25 years old, participated in this fMRI study. Imaging data was acquired using a GE 3T TRIO MRI scanner. On the stimuli page, there were one piece of negative review about product quality, one piece of feedback specifically designed for this negative review and a marking item for subject satisfaction. We totally set five kinds of negative review

and three kinds of feedbacks (apology、explanation and a simple gratitude feedback), which formed 15 different stimuli pages. fMRI data preprocessing was performed with Statistical parametric mapping software (SPM8) and Data Processing Assistant for Resting-State fMRI(DPARSF) implemented in Matlab 2008a. Results: (1) Behavior data. A post hoc test, a significant increase in the rating score in apology condition (M = 2.91) compared to explanation condition (M= 2.10) ($p< 0.001$) and the rating score in explanation condition (M = 2.10) compared to none condition (M = 1.33) ($p< 0.001$). (2) fMRI data. fMRI further explored the neurological mechanism of two feedbacks, through which we found that the right angular gyrus, left insula, bilateral ACC, bilateral thalamus and bilateral Cerebellum were activated both in the explanation and apology condition. And the activation in bilateral amygdala (the key region for negative emotion processing) was deceased under the apology condition, while not under the explanation condition. Conclusions: We proved behaviorally and neurologically that both apology and explanation have a significant impact on the recovery of trust, but apology is more effective in redeem the damage caused by negative reviews. Apology can significantly reduce the activation level of amygdale, which associated with negative emotion processing, thus has a stronger effect on repair consumer's satisfaction. Support: This research was supported by National Natural Science Foundation of China (71471019, 71671115， 71772124), Shanghai Institutions of Higher Learning (No.TP2015031, TP2016020).

E. Consumer Behavior & Marketing

2-E-20 Arousal and attention in dynamic investment decisions

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Objective: Theories of financial decision making in economics and finance assume that investing choices are governed by statistical calculations of risk and returns. In contrast, empirical and experimental research suggests that asset prices are influenced by emotional factors such as investor sentiment, excitement, or even panic. These emotional factors are all associated with physiological arousal, which in turn regulates attention and information processing. Our objective was to explore the relationships between physiological arousal, attention, and investment decisions in a dynamic setting where economic theory provides a natural benchmark for behavior. Methods: 47 participants made a series of investment decisions by allocating their assets between a risky and a safe option in two blocks involving 40 decision rounds each. A bivariate Markov process with a good and a bad state determined the expected return from the risky asset in each round. Expected returns were positive in the good state and negative in the bad state, and the two blocks differed in the level of Gaussian white noise associated with the random return, either high or low. Each period we observed participant investment decisions together with pupil dilation and gaze fixation collected via an EyeLink Plus 1000 eyetracker (SR Research). Results: We found that pupil diameter was 1) positively associated with the allocation to the risky asset in the current round and 2) negatively associated with the change in allocation in the subsequent period. In addition, pupil diameters were smaller when investment allocations were consistent with Bayesian decision-making (high allocations when the probability was high and low allocations when the probability was low), while pupil diameters were greater when participants made choices inconsistent with Bayesian decisions. We also found that participants whose behaviors were consistent with Bayesian decision-making paid significantly more attention (gaze fixation and duration) to information about price changes and total current asset values. Conclusion: Our results suggest that arousal systems play an important role in investment decision-making. Consistent in large part with the adaptive gain model of locus coeruleus - norepinephrine function (Aston-Jones and Cohen 2005), Bayesian decisions are associated

with decreased pupil-linked arousal (exploit), while non-Bayesian decisions are associated with increased pupil-linked arousal (explore). However, we also find a strong relationship between increased arousal and a reduction in risk-taking. Higher levels of arousal appear to be associated with normatively suboptimal investment choices.

F. Intertemporal Decision-Making & Self-Control

2-F-21 Using a two-player interactive game to study strategic competition, its neuronal correlates, and the effects of a third observer

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Primates including humans exhibit complex behaviors when interacting with their conspecifics. Laboratory studies of primate sociality, however, routinely employ choice tasks in restricted action space, affording poor external validity and limited numbers of behavioral markers to compare across species. In the current study, we preserved the dynamic nature of social interactions by examining the simultaneous, continuous behaviors of pairs of humans or rhesus macaque monkeys playing a zero-sum competitive soccer game. To win a point, one player (the kicker) had to maneuver a ball across the screen while the other player (the goalie) attempted to intercept it. We found that in this game the interactions between human pairs (n = 9,000 trials) and monkey pairs (n = 11,600 trials) were similarly complex, and this complexity could be disentangled and reliably categorized into a set of strategies: overall, the kicker won by being unpredictable whereas the goalie won by accurately responding to the kicker's movements. Even though the interaction between players ultimately dictated the game, gaze patterns and pupil sizes in both players predicted ball position and trial outcome before either player started to move. In monkeys, we also recorded single unit activity from a subregion of Superior Temporal Sulcus (mSTS), a potential homologue to human Temporo-parietal Junction (TPJ). We found that for both kicker (n = 133) and goalie (n = 125) mSTS neurons signaled strategy during the task phase and trial outcome during the reward phase. In addition, mSTS differentiated between social contexts (kicker n = 772 neurons in 5 conditions, goalie n = 432 neurons in 3 conditions) and was most robustly activated by competition with live opponents, even in the absence of visual social cues. Finally, we found that adding a third observer monkey to the game and randomly assigning him to either the kicker or the goalie's team (and thus getting rewarded together with his teammate) greatly impacted behavioral performance as well as mSTS activity in the players. Specifically, when the observer was put on the kicker's team, the kicker won more frequently and mSTS signals associated with strategy and trial outcome were amplified. We also found that spiking and LFP activities in the kicker de-correlated from those in the goalie when the observer was on the kicker's team. Together, these results demonstrate the feasibility of using two-player interactive games to study complex social behavior, strongly implicate the primate mSTS in encoding the strategies of self and others during live interactions, and support the hypothesis that this area is the homologue of the human TPJ.

2-F-22 Understanding cooperation as a social strategy

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Real world decisions are usually made within a social context. Many of our actions are chosen considering vicarious feelings of another's reward or pain. However, there are times where this desire for another's wellbeing is in conflict with self-interest, resulting in the need to rely upon strategic reasoning about the beliefs, desires, and goals of others to make our decisions. We are interested in the act of cooperation, especially in the absence of communication and corroboration between participants. We

use a novel paradigm, based on the game theory game of 'chicken' to allow interactive play. This task gives each player two choices which results in four different outcomes, the one which is of most interest is when both players choose to cooperate. The payouts vary between trials, and are not necessarily symmetrical between the players. We predict (and demonstrate) that players are likely to favor cooperation when the disparity between the cooperative payout between the players is small, and tend towards non-cooperation when the disparity is large. We also modelled each player's choice behavior by combining a simple reinforcement learning system with an expected value model. The player is able to calculate the expected values of their actions given their belief regarding their partner's behavior - i.e. how likely are they to make one choice over another. We have modeled the form of this belief in a variety of ways, and find that models which incorporated recursive reasoning of the partner's subjective utility can better predict the players' actions. Individuals with high risk taking scores took their partner's perspective less as measured by the improvement of the behavioral model that included recursive reasoning as a factor. Additionally, the model demonstrates that players that place higher subjective utility on cooperating ultimately earn bigger monetary rewards for both themselves and their partners. This suggests that humans rely upon recursive reasoning, ie modeling of their partners' intentions to carry out gameplay in this task. The ability to do so is advantageous for coordinating cooperative behavior, and results in benefits to the group.

2-F-23 A frontoparietal (FP) network implements the updating of both game and strategy information

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OBJECTIVE Most real-life interactions are repeated encounters, modeled in game theory (GT) as stochastic games where the players play a sequence of possibly different stage games. We explore the neural basis of updating information on critical game variables during strategic playing where the game or partner's strategy may change. Subjects are modeled as using rules associating game and player to a choice. METHODS Forty-two subjects played a stochastic game during fMRI scanning, matched with 6 players, 2 of them following each of 3 different strategies. Stage games were Prisoner's Dilemma (PD) and Battle of the Sexes (BoS). First, information about the opponent player (i.e., one of the 6 players) and the game to be performed (PD or BoS) appeared on the screen, followed by a delay where the subject maintained all available information and made a choice. Finally, feedback on choices made by both players was displayed. Subjects also completed an intelligence test outside the scanner. We classified subjects in 3 groups: people who responded optimally to all players in both games, thus integrating proactively information about the partner's strategy and the active game; people who responded optimally only in PD; those who did not respond optimally in any game. We contrasted brain activity in trials where the game (strategy) changed with trials where the game (strategy) was identical to the previous round to identify brain regions implementing game (strategy) information updating. RESULTS A frontoparietal network (FPN) including dorsolateral prefrontal cortex, posterior parietal cortex and premotor cortex was involved in updating game and strategy information in subjects who learned the game structure. By contrast, no region showed increased activity for game/strategy switches in the third group, reflecting the fact that this group did not learn to integrate information about the game variables maintained in working memory (WM). Performance in the game correlated with individual measures of intelligence and FPN activation, with higher scores associated with higher payoff and FPN activation. CONCLUSION A FPN implements information updating in strategic interactions where subjects keep track of game and partner's strategy; its enrolment is essential for the implementation of the optimal response to game and opponent. The association between intelligence, performance in the game and

activation suggests that proactive WM integration is essential in implementing rules in games, and it is responsible for observed systematic differences in behavior due to Intelligence.

G. Game Theory & Strategic Interactions

2-G-24 Sex differences in effort discounting in late middle-age but not younger adulthood

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Prior studies have suggested that dopamine function impacts willingness to expend physical effort for rewards. Well-documented declines in the dopamine system with age that begin in early adulthood would suggest that tolerance of physical effort costs would also decline with age but that dopaminergic drugs may be able to recover tolerance of physical effort. The goal of the present study was to examine age differences in effort discounting and the effects of dopaminergic drugs on effort discounting in healthy adults. Seventy-three healthy young adults (ages 20-29, n=40) and late middle-aged adults (ages 50-65, n=33) completed an incentive-compatible physical effort-based decision-making task while undergoing fMRI. A subset of forty-five of the same healthy young adults (ages 20-29, n=22) and middle-aged adults (ages 50-65, n=23) also took part in a randomized double-blind, placebo-controlled study during which they were administered either a moderate dose of d-amphetamine (M = .43 mg/kg, SD = . 018) or placebo on separate visits and then completed the same effort task. We did not find the expected age differences in effort discounting in any condition but did observe interactions of age and sex on baseline preferences and drug effects on preferences. There was a sex by age interaction on baseline preferences $F(1, 69) = 7.58$, $p = .008$, $n2 = .10$, such that middle-aged men had lower effort discount rates (i.e., were more willing to choose the higher effort, higher reward option) than middle-aged women, $F = 6.72$, $p = .012$. There was no sex difference for younger adults, $F = 1.53$, $p = .221$, whose preferences were similar to middle-aged women. There was not a main effect of drug on effort discounting, $F(1, 41) = 1.35$, $p = .252$, $n2 = .03$, but there was a drug by sex by age interaction, $F(1, 41) = 8.86$, $p = .005$, $n2 = .17$, such that the only group of individuals who showed a significant drug effect were the middle-aged men. For middle-aged men, d-amphetamine increased effort discount rates (i.e., less tolerant of effort costs) relative to placebo. Although we initially expected variance in preferences to be accounted for by age rather than sex, recent studies have documented a lack of age differences in adulthood and sex differences consistent with our finding that men were more tolerant of effort costs than women. In addition to completion of the effort task while undergoing fMRI, participants also completed multiple PET scans to assess dopamine receptors, release, and transporters. Future analysis of the neuroimaging data may reveal additional individual difference effects that account for both age and sex differences.

2-G-25 Reciprocal fairness, punishment and reward in 2nd and 3rd party interactions.

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Fairness is a hallmark of our species, helping to maintain cooperative relationships in our society. We tend to punish those who violate social norms of fairness and to reward those who respect them. Sanctions and rewards can be applied by someone who is the target of the action or by an unaffected third party and punishment and reward can be more or less costly. Despite the evidence showing that people are willing to engage in punishing and rewarding behavior in both 2nd and 3rd party interactions, the exact neurobiology behind these forms of reciprocity is still unclear. Different theories have been proposed for the involvement of a prefrontal network in norm enforcement, but their predictions have

not been directly tested in a study that allows a clear untangling of the roles of different prefrontal areas. This project consists of a behavioral study aimed at analyzing punishing and rewarding behavior, and of a brain stimulation study in which we test the predictions of different neurobiological models of fairness evaluation in social interactions and norm enforcement. METHOD: In the behavioral study, 72 subjects participated in a two-stages three-persons dictator game with punishment and reward. In the first stage, a Proposer allocates part of his endowment to a Receiver. In the second stage, either the Receiver or an unaffected third player, the Observer, can modify (i.e., increase or decrease) the Proposer's payoff after learning the allocation. In a within-subjects design, subjects face 140 real allocations ranging from very selfish to very generous. We implement a 2x2 design where we vary the personal involvement of the player in the situation to assess (i.e. 2nd vs. 3rd party interaction) and the cost of punishing and rewarding behavior (i.e., costly vs. no costly reaction). RESULTS: Behavioral results show that subjects punish allocations below the equal split and reward allocations above the equal split. In addition, subjects punish and reward more when norm enforcement is cost-free. Subjects react similarly when they are the target of an action (i.e, 2nd Party conditions) compared to when they are not directly involved (i.e., 3rd Party conditions). CONCLUSION: The results from the behavioral study show the existence of negative (i.e., punishment) and positive (i.e., reward) in both 2nd and 3rd party interactions with or without cost. Using continuous theta burst stimulation, we now plan to investigate the neurobiological mechanisms of punishment and reward in 2nd and 3rd interactions and we aim to establish a causal link between right dorsolateral prefrontal cortex and medial prefrontal cortex and norm enforcement.

2-G-26 Borderline personality and perceived trustworthiness of others modulates learning mechanisms in social trust exchange

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Borderline personality disorder (BPD) is partly characterized by impulsive, maladaptive behaviors that are often precipitated by interpersonal stressors. Prior research suggests that patients with BPD make disadvantageous decisions during social economic exchanges in response to perceived unfairness by the partner (King-Casas et al., 2008). We aimed to characterize neurocognitive mechanisms that contribute to disadvantageous decision making in BPD. 83 participants completed a social trust game (age: M = 20.80, range 13-30; n BPD: 40; n HC: 43). Drawing on a social trust task in which participants could invest money in a social economic exchange partner who had the option to share the profit with the investor (i.e. the participant; Delgado, Frank, & Phelps, 2005), participants had the option to invest in the social economic exchange partner on each trial. Participants were also explicitly provided feedback of the social economic exchange partner's decision, even on trials in which the participant did not choose to invest in the partner. This enabled us to examine how participants learn from trials in which they chose not to invest in their exchange partner due to perceived unfairness. We examined whether decision-making in BPD could be influenced by dispositional mistrustfulness, as well as the reputation of the partner in this task. Finally, we used model-based fMRI to examine neural mechanisms that contribute to disadvantageous decision-making in individuals with BPD symptoms. Using computational reinforcement learning, we found that BPD participants' greater mistrustfulness of others was associated with reduced sharing with the trustee, even when controlling for BPD participants' overall bias away from sharing. Initial model-based voxelwise analyses (FSL FLAME) of controls indicated that the ventral striatum was involved in how participants adjusted their rate of cooperation based on experience; striatal learning signals reveal a self-centered instrumental process that supported reciprocal altruism. We plan to extend these model-based analyses to examine activation differences in subjective value and reward prediction

errors, which partly explained behavioral differences in the BPD group. In line with observed behavioral findings, we expect the BPD group to exhibit attenuated striatal activity on trials for the trustee with a negative reputation. This work provides insight in potential neurocognitive mechanisms underlying disadvantageous decision making in BPD.

2-G-27 Effects of age and gender on risk-taking across the life span

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Objective: Risk is ubiquitous in human life and people need to make numerous decisions under risk across the life span. One of the dominant findings in the literature is that people typically becomes more risk-averse when getting older. However, some studies have reported opposite findings that older adults may be more risk seeking in the risk tasks and more likely to make financial choices involving greater risk. The Balloon Analog Risk Task (BART) is a widely used and ecologically validated cognitive test for assessing risk-taking performance. In this study, we used the BART to examine the effects of age and gender on people's risk-taking behavior in a large sample of healthy individuals across a broad range of age. Methods: A total of 754 participants (307 males; age 16-76 yrs) completed a web-based modified version of the BART. During the task, they were repeatedly given the option to continue or discontinue inflating a virtual balloon that could either grow larger or explode. A larger balloon was associated with a greater risk of explosion as well as increased amount of reward points. Each participants completed 30 balloon trials. The average number of inflation pumps participants made for the winning balloons were calculated as the objective measurement of risk-taking propensity. Participants' sensitivity to loss (punishment) were measured by the change of inflation number after negative outcomes compared to that after positive outcomes. Results: A significant gender effect was found on participants' risk-taking behavior. Specifically, females made significantly less inflations than males ($p<0.001$). A negative age effect was also observed on risk-taking behavior for participants older than 40 yrs ($p<0.001$), whereas no effect of age on risk-taking behavior was found for participants below 40 yrs. Both age and gender showed significant effects on participants' sensitivity to loss. Females were more sensitive to loss outcomes and reduced inflation pumps more than males after the balloon explosion, whereas older participants were less sensitive to loss outcomes and did not change the number of inflations after the balloon explosion. Conclusion: To our knowledge, this study is the first study using the BART to measure individual risk-taking behavior across a broad range of age in a large cohort of participants. Consistent with previous studies, females are more risk-averse than males, and older adults are more risk-averse than younger adults. Moreover, older adults did not adjust their risk-taking behavior after loss outcomes, suggesting that aging may be associated with learning dysfunction from negative feedbacks during risky decision making.

H. Learning & Memory

2-H-28 Parsing the role of dopamine in reward discounting and subjective valuation

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Some people are more willing to make impulsive, risky, or costly choices than others, which has been assumed to be strongly associated with individual differences in dopamine (DA) function. Much attention has focused on DA D2 receptors, which inhibit impulsive motor action and are implicated in motivation-related tonic DA signaling. Similarly, discounted subjective value representations in the ventromedial prefrontal cortex (vmPFC) are believed to be driven by dopamine signaling. However, few studies offer

clarity on the association between DA D2 receptors, discounting behavior, and the neural representation of subjective value. In a multimodal brain imaging study and two meta-analyses, we sought to clarify these associations. We scanned 84 healthy adults with PET imaging and [18F]fallypride, a radioligand that binds to D2 receptors in the striatum. A subset of these participants (N=22) completed a delay discounting task during an fMRI scan. In the larger sample, striatal D2 receptor availability was not directly correlated with discounting behavior. In the subset of subjects that completed both PET and fMRI, we identified a novel link between D2 receptors in the ventral striatum and subjective value representation in the vmPFC. A follow-up meta-analysis of studies of individual differences in DA PET measures and discounting in humans (N=17 effects) corroborated our null findings between striatal D2 receptors and discounting behavior, but also suggested that the nature of individual difference associations between DA and discounting depends on DA-related psychopathology. In a second meta-analysis, we examined the impact of pharmacological manipulation of the DA system from placebo-controlled studies of discounting using humans, non-human primates, and rodents (N=61 effects). DA drug effects suggested a more nuanced relationship between DA receptors and reward discounting with non-significant differences in effects on discounting between agonist and antagonist drugs that bind to D1 or D2 receptors. Alternatively, drugs that bind to DA transporters, which clear extracellular DA, consistently decreased reward discounting. Together, the data suggest that the relationship between individual differences in DA receptors, discounting, and neural representations of value are not as clearly linked in healthy humans as many in the field have assumed. The strongest associations were observed between DA receptors and neural representations of subjective value but overall, in our own data and across the existing literature, there were no reliable direct associations between DA D2 receptors and discounting behavior in healthy humans.

2-H-29 Two paths to patience: Individual differences in deliberate, but not automatic, intertemporal choice predict model-based planning in humans

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Objective: Patience in intertemporal choice tasks (ITC) predicts several other controlled behaviors. Recent research shows that "model-based" planning in sequential reinforcement learning (RL) tasks may similarly index trait control. Do these measures reflect a common mechanism? Recent theoretical work (Gabaix & Laibson 2017) suggests that temporal discounting can arise without time preferences when rational agents evaluate choices by simulating consumption events. When simulation variance increases with time to consumption, the agent will discount future rewards. One mechanism to generate simulations with this property is sequential sampling from memory (Shadlen & Shohamy 2016; Bornstein et al 2017), also thought to underlie model-based planning in sequential decisions (Bornstein & Daw 2013; Doll et al 2015). A potential correspondence is supported by recent observations that individuals discount rewards less steeply when using memory to construct richer representations of future outcomes (Peters & Büchel 2010). However both patience in ITC and goal-directed behavior in RL can also result from non-deliberative mechanisms (Miller et al 2016). Here we ask whether and how individual differences in these faculties are related. Methods: Participants (N=483) performed a standard ITC task, selecting between smaller immediate monetary rewards and larger time-delayed amounts. A subset (N=31) also performed a "two-step" RL task (Daw et al 2011). For ITC, we fit hyperbolic discount rates and choice noise. We also fit a sequential sampling model (DDM; Ratcliff 1978) which provides separable measures of individual bias and rate of deliberation. For RL, we fit an index reflecting participant's reliance on a model-based, rather than model-free, choice strategy. Results: Though both choice bias and deliberation rate were each separately correlated with discount factor, only rate

predicted noise. Similarly, model-based choice tracked shallower discounting, but was exclusively correlated with the rate, not the bias, of the DDM. Conclusions: These results support a common capacity for deliberative evaluation in both planning during RL and patience in ITC. Though patient decisions can, like goal-directed choice, result from deliberative or reflexive mechanisms, our results suggest that only the deliberative component may generalize across tasks. One implication is that treatments aiming to improve patience should focus less on building good habits (e.g. commitment) and more on building capacity for deliberation. Acknowledgements: This work was supported by NIH Grant R03DA038701, NSF CAREER grant 1654393 and a generous gift from the Mortimer D. Sackler MD family.

2-H-30 The cost of cognitive control and the balance of random versus directed exploration

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Objective: Evidence suggests exerting cognitive control carries an intrinsic cost and that individual differences in subjective costs may account for differences in everyday control allocation. We present two studies: study 1 develops novel methods for quantifying the cost of cognitive control; study 2 tests the hypothesis that control costs modulate the tradeoff between directed exploration (a cognitive strategy assumed to be more demanding) and random exploration. We predicted that participants who express a higher subjective cost of control would engage in more random and less directed exploration. Methods: In study 1 we assessed the relationship between two measures of the cost of control. The first method quantifies control costs using a patch foraging paradigm where participants (N=18) had to complete a control-demanding task (N-Back) to travel between patches. We predicted that participants would over-exploit a patch, yielding diminishing rewards, when more demanding levels of N-Back are required to travel. We used the Marginal Value Theorem to quantify the amount of reward forfeited. In the second method we estimated how many word-reading (WR) Stroop trials participants would complete to avoid a (control-demanding) color-naming (CN) trial. In study 2 we tested the relationship between individual differences in control costs and the use of random versus directed exploration using the Infinite Bandits Task (N=34). In the task participants choose between exploiting a known bandit or exploring an unknown bandit which may increase the exploit value. Results: Most participants treated control as costly in both tasks in study 1, and there was a significant positive correlation between the cost of control associated with the N-Back task and with the CN Stroop task within a participant. In study 2 we did not replicate the positive relationship between those tasks. We replicated group-level demand avoidance in the Stroop task but not in the foraging task. In the Infinite Bandits task participants did not adjust their strategy in response to experimental manipulations. We found no relationship between cost of control and Infinite Bandits task. Conclusions: These studies showed that people will complete additional WR Stroop trials to avoid CN trials. We did not find consistent demand avoidance in this patch foraging task, however patch foraging tasks may still be a useful method to implicitly measure control costs. More research is needed to see why study 1 results do not replicate, and follow-up studies will use a different exploration strategy measure.

2-H-31 Neural evidence that delayed rewards are less concrete

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Intertemporal choice - choice of smaller reward now versus a larger reward later - is one of the most important behaviors of study across a variety of disciplines. A wide variety of behaviors such as investing in stock markets for future returns to abstaining from smoking for future benefits in health can be described as intertemporal choice. Typically, delayed rewards are often objectively better than immediate rewards, but are less desirable due to their delay. Why, however, are delayed outcomes less

desirable? Several different theories propose that future outcomes are less desirable because they are less concrete. Rick and Lowenstein (2008) argue that delayed outcomes tend to be less tangible than immediate outcomes (e.g., smoking now has immediately perceivable pleasure; the promise of better future health is less appreciable). In a similar vein, construal level theory (Trope & Liberman, 2010) proposes that when people think of future events, they use high-level construal to represent events in abstract ways, while for immediate events, they use low-level construal to represent them in a concrete manner. Testing these theories, however, is tricky, as it requires a reliable measure of abstract versus concrete thinking. Here we develop and use neural indices of the concreteness of imagination to test these ideas. First, using a dataset in which participants were instructed to imagine possible future events that varied in their degree of vividness, we built a whole-brain neural predictor of imagination vividness. This predictor puts the largest positive weights on activity in the central OFC and hippocampus. Importantly, as the vividness of the scenarios in this study was counterbalanced across positive and negative valence, the whole brain predictor of vividness was orthogonal to one that predicted imagination valence. Consistent with previous work, this predictor puts the strongest positive weights on activity in vmPFC and PCC. Then, in two separate intertemporal choice fMRI datasets, we show that the whole brain neural predictor of imagination concreteness predicts the temporal distance to the delayed reward, but not its amount, exactly as would be predicted if delaying rewards elicited less concrete thinking. Consistent with previous work, the whole brain neural predictor of imagination valence predicts the subjective value of the delayed reward. These results demonstrate that, consistent with several prominent theories, people engage in less concrete thinking about delayed rewards, which could explain in psychological terms why they are discounted relative to immediate ones.

2-H-32 Temporal adaptation of decision-making patterns in delay-discounting bundles

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Subject's choices are not perfectly reliable even when the choice parameters and available information are held constant. Instead, choices depend on current context, order of presentation and other task features. These phenomena have been well-described for the context-dependence of the value of goods: framing effects, reference point effects, order effects, etc. In a recent study designed to examine stability of time-preferences between short and long delays, we found evidence that the encoding of time in delay-discounting may be subject to similar contextual effects as the encoding of value. Here, inspired by a recent showing how preceding offers act to normalize the encoding of the present offer, we designed a study to quantify how the recent history of delayed-offers normalizes current delayed-offer. Consistent with previous research, blocks of trials contained a mix of "bidding" (B) and one of the two types of "adaptation" (A) trials, thus 5 blocks total following the sequence: B - A - B - A - B. In the bidding blocks, subjects revealed the minimum amount of coins they are willing to accept now, instead of a delayed bundle (e.g., 10 coins in 3 days). The first bidding block was used to order the bundles by their bid value. In the adaptation blocks, either high or low value bundles were presented and bids of subsequent bidding blocks were tested against previous bidding values for the same bundles. We used two types of adaptations (between subjects): choice and rating. In the former the subject was asked to make a choice between the presented bundles and constant number of coins today, whereas in the latter subjects rated selected bundles on a pleasantness scale. We find that the adaptation effect, i.e. difference in bids, is more pronounced in rating than in choice adaptation types, in high-low than in low-high order of adaptation blocks and towards the higher subjective bundle values. However, choice and rating adaptations result in directly opposite effects: overbidding in the former and underbidding in the latter after high value bundles.

2-H-33 The neural mechanisms of self-deception

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Self-deception is common in our everyday life. According to Rrivers et al., self-deception makes it easier to convince or deceive others (Trivers, 1985, 2011; Von Hippel & Trivers, 2011). People who exploited opportunities to cheat on tests were likely to engage in self-deception (Chance et al., 2011). In addition, a functional magnetic resonance imaging (fMRI) study investigated self-deception by asking participants to complete a Balanced Inventory of Desirable Responding test in the scanner (Wilkinson & Hunter, 2015). They found that self-deception was associated with the medial prefrontal cortex and left ventrolateral prefrontal cortex. But the neural process of deceiving oneself while making decisions is still unclear. To investigate the neural mechanisms underlying self-deception, we conducted an event-related fMRI experiment (within-subject design), using a modified numerical discrimination task (Halberda et al., 2008) with real payoffs. In the first session, participants first performed a numerical discrimination test with answer cues (i.e. decision phase). Afterwards, participants received the feedback of their performance. They were also asked to report whether they could finish the task without answer cues by pressing buttons to select "able" or "unable" (i.e. prediction phase). If their prediction error is less than 10%, they can earn extra payoff. In the second session, participants completed the numerical discrimination task without answer cues and feedback. Third-four healthy participants (15 female) attended the experiment. For each participant, brain activation was estimated using a general linear model. With regard to behavioral results, we found that the participants' degree of self-deception positively correlated with the subjective proficiency of the task which not significantly correlated with their actual proficiency of the task (i.e., performance in the second session). With regard to the fMRI results, comparing with the honest condition, self-deception condition significantly activated the right medial frontal gyrus and the right posterior cingulate in the decision phase (Voxel-level threshold $p < 0.001$ uncorrected, cluster-level $p < 0.05$, FWE corrected), if they reported "able" in the prediction phase. Our study investigated the neural mechanisms underlying self-deception. The behavioral results suggested that self-deception boosted individuals' self-confidence regardless their actual capacity. The neuroimaging results suggest that self-deception is associated with the fronto-parietal network. These findings may help explain the prevalence of self-deception and shed light on the underlying neural mechanisms.

2-H-34 Would you like fries with that? Modeling the default effect in dietary choice

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Although bias toward the default option in a choice set has been employed to alter choice across domains from finance to organ donation, it has received little attention in dietary choice. Because dietary choices often feature an unhealthy default - for example, french fries and soda in fast food meals - this presents an unexploited opportunity to improve choice. Here, we find that providing a healthy default, even if it is less tasty than the alternative, significantly improves dietary choice both compared to cases in which no default was present, and when the default was unhealthy. Eye gaze analysis indicates that the default draws attention first and holds it for longer, contributing to its advantage in choice. Counter-intuitively, response times were longer when a default was present, suggesting subtle changes to the decision process rather than the engagement of a heuristic, which was tested using model comparison. Multi-attribute drift diffusion modeling revealed that providing a default food decreased the weight placed on both the tastiness and healthfulness of options during evidence accumulation and slowed the processing of taste information, which contributed to the observed slower response times. Together,

these results suggest that defaults may engage a more deliberative decision process that slows responses to facilitate healthier choices. Further, this implies that replacing unhealthy defaults with healthier alternatives could be a simple way to profoundly improve health outcomes for many consumers.

2-H-35 Neuromodulatory and structural substrate of intertemporal choices in younger and older adults

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The neuromodulatory and structural brain basis of interindividual differences in how people discount future rewards is not yet well established despite its vast importance for understanding both healthy functioning and psychiatry disorders. Here we present results from behaviour and neuroimaging analysis from two human cohorts. For each participant, we assessed delay discount rates fitting a hyperbolic model to data from a standard intertemporal choice task. We also generated maps of grey matter volume (GMV) and fractional anisotropy (FA, a measure of white matter microstructure organization) and estimated the volume of subcortical brain structures as well as total cortical volume. In the first sample (903 younger adults, 22-37 y from the Human Connectome Project dataset), more impulsive discounting was associated with smaller total cortical volume and putamen volume. We also decomposed the GMV and FA data in structural covariance networks using independent component analysis. More impulsive discounters had less GMV in in a network loading primarily on bilateral temporal pole and middle-temporal regions, but higher FA in a network loading mainly on frontal white matter overlapping with the uncinate fasciculus and the forceps minor. We then projected the GMV and FA data of the second sample of 30 younger (19-32 y) and 30 older (66-75 y) adults onto these two structural networks. In this sample, older individuals discounted future rewards significantly more than younger ones, and had reduced GMV and FA values in the identified structural networks. FA values in the frontal white-matter component were positively correlated with discount rates after controlling for age, as in the first sample. We also estimated dopamine D1 receptor binding potential (BP) using the tracer [11C]-SCH23390 and found a positive age-corrected association between discount rate and D1 BP for the pallidum. These results link choice impulsivity to cortical and subcortical grey matter volumes, and to the microstructural organization of frontal white matter and dopamine neuromodulation in the basal ganglia. Both microstructural organization and dopamine neuromodulation predict delay discounting independently of their reduction with age.

I. Valuation & Value Systems

2-I-36 Adolescent-specific attenuation of Pavlovian constraints on instrumental learning

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Individuals must learn to cope with distinct environmental challenges. Multiple learning systems allow individuals to acquire a repertoire of behaviors to respond to these diverse demands. Through Pavlovian learning of stimulus-outcome expectancies, cues that predict reward elicit behavioral approach, whereas cues that predict punishment lead to behavioral inhibition. In contrast to these hard-wired responses, instrumental learning of action-outcome contingencies affords behaviors that flexibly and deliberately bring about desired outcomes. Reflexive Pavlovian responses have been found to constrain flexible behaviors through either facilitating or undermining instrumental learning. When the Pavlovian tendency to approach reward or inhibit action in the face of threat is aligned with the instrumental

response, reward-driven instrumental actions are invigorated and instrumental actions to punishment-related cues are inhibited. When Pavlovian and instrumental responses are in conflict, Pavlovian biases can interfere with learning adaptive, instrumental behaviors. Pavlovian constraints on instrumental learning are evident in adults but have yet to be well characterized across development. In this study, we examined the extent to which children, adolescents, and adults (n = 61, aged 8-25) exhibited Pavlovian biases on learning action-outcome contingencies during a Go/No-go task in which valence and action were orthogonalized. Pavlovian and instrumental responses were aligned for two trial types (Go to win, No-go to avoid losing) and in opposition for two trial types (Go to avoid losing, No-go to win). We found a valence-by-action-by-trial interaction that was differentially impacted by age. Children's and adults' performance was enhanced when Pavlovian and instrumental responses were aligned versus in conflict, representing a valence-by-action interaction. However, as shown by comparable performance across trial types in adolescents, Pavlovian biases on instrumental learning were suppressed during this developmental period. Reinforcement-learning models corroborate an adolescent-specific attenuation of Pavlovian biases. Developmental shifts in the contribution of different learning systems may foster adaptive behaviors during the transition into adulthood.

2-I-37 Adult age differences in d-AMPH effects on model-based learning

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Age-related declines in learning have been assumed to be due to loss of dopaminergic function; administration of a dopamine precursor has been shown to enhance simple reinforcement learning in older adults. However, no prior studies have directly compared younger and older adults to examine the potential differential effects of dopaminergic drugs on reinforcement learning. Here we used a model-based decision-making task to examine adult age differences in learning after administration of oral placebo or d-amphetamine (d-AMPH), a drug that increases synaptic dopamine levels. Healthy, drug-free younger (YA, ages 20-30, N = 20) and late middle-aged (MA, ages 50-65, N = 24) adults completed a multi-day, multi-modal neuroimaging study at Vanderbilt University. Participants completed 132 trials of a model-based sequential learning task under placebo and d-AMPH. On each trial, participants were instructed to initially choose between two options represented by fractal images (Stage 1), which led to two different probabilistically-determined (70% vs. 30%) second stages. Once in Stage 2, participants once again chose between two images to earn a monetary reward. Learning was assessed by examining the effects of transition type (common or rare) and reward on their subsequent Stage 1 behavior (stay or switch) or Stage 2 reaction time. We generally expected that d-AMPH would improve model-based learning in both age groups. We did not see the predicted effects of d-AMPH on model-based learning across age groups. However, there were differential effects of drug by age group. We found that MA participants were more likely to stay than YA participants, but this was shifted by d-AMPH. While d-AMPH had no effect on YA stay probability, MA participants were less likely to stay on d-AMPH. Further, contrary to our expectations, d-AMPH slowed participant responses, but this effect appeared to be driven predominantly by the MA participants, who were significantly slower on d-AMPH than when off. As expected, we saw that people were slower to respond following a rare transition. However, this depended on group and drug status. While MA participants were significantly slower on d-AMPH following both transition types, YA participants were only slowed down by d-AMPH on rare transitions. Our results suggest that dopaminergic drugs can have differential effects on learning and decision making across the adult life span. Future analyses will use additional collected PET data to examine how drug effects may be related to individual differences in dopamine receptor availability, dopamine release, or dopamine transporters.

2-I-38 Negative prediction error looms larger than positive prediction error

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OBJECTIVE: Reinforcement learning models typically assume a fixed learning rate for both positive and negative prediction errors. Recently, many studies have shown that positive and negative events often do not have symmetric impacts on human behavior and distinct circuits within cortico-striatal loops appear to support learning from better-than-expected outcomes and worse-than-expected outcomes. Studies assuming dual learning rates have inconsistent conclusions about whether human learn more from positive or negative prediction errors, as evidenced in studies of optimism bias and fear conditioning. Here we designed three experiments with probabilistic instrumental learning tasks to investigate the relative impact of positive and negative prediction errors on learning. METHODS: We conducted three experiments in which subjects made a series of choices between options with probabilistic payoffs. In Experiment 1 and 2, each option was associated with a stationary probability of monetary gain or loss. However, in Experiment 1, same option pairs were presented intermittently (~4 trials on average), whereas in Experiment 2 learning of the same option pair was completed one pair at a time. In Experiment 3, the probability of rewards associated with each option was determined by a random walk process to ensure constant learning. RESULTS: We adopted the Q-learning model with two learning rates - one with positive prediction error (i.e. positive learning rate or LRp) and the other with negative prediction error (i.e. negative learning rate or LRn) to fit subjects' choices. We hypothesize that the learning of sparsely presented options might engage additional learning mechanisms such that the learning rate estimated from Experiment 1 & 2 might be different. Indeed, in accordance with previous literature, LRp is bigger than LRn in experiment 1. This pattern disappeared in Experiment 2 when learning is more based on the cached expectations. We further conjectured that using stationary probability may not be an appropriate approach to investigate the progress of learning since learning can quickly saturate within a few trials (our data showed that the sum of prediction errors in the first fourth trials could sufficiently predict the choice rate of subjects' preferred option, that is, the option chosen in more than 50% of the trials). In Experiment 3, in which constant learning were encouraged, LRn was robustly larger than LRp, in all three gain, loss, and mix blocks. CONCLUSIONS: Humans were more sensitive to negative prediction error than positive prediction error.

2-I-39 Learning optimal bayesian strategy through observation

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Objective. In stochastic environments it might be not apparent if an observed behavior is optimal or not. Therefore, it is not clear whether people will be influenced by observing someone who chooses in the same environment and how it depends on the optimality of the observed choices. We study choices in a class of 2-armed bandit problems with known optimal Bayesian strategy and test how the ability to predict the behavior of a human demonstrator with high or low percentage of optimal choices influences the performance. Methods. In phase 1 of the experiment, 162 participants choose in 12 different 2-armed bandit problems each lasting for 10 periods. They are told that the probabilities of reward from the two arms in each problem are uniformly and independently distributed (which allows us to compute the optimal Bayesian strategy). In phase 2, half of the participants repeat phase 1, and we use their data to choose two demonstrators: one with high percentage of optimal choices (86%) and one with low (47%). Another half of the participants in phase 2 are paid to correctly predict the choices of either one of the two demonstrators. They observe which arm a demonstrator has chosen and which payoff she received, and are asked to predict the next choice. In phase 3 all participants make individual choices as

in phase 1. Results. We find that the percentage of optimal choices between phases 1 and 3 significantly increases for the low optimality participants who predict the behavior of the high optimality demonstrator. To the contrary, the percentage of optimal choices significantly decreases for the high optimality participants who predict the choices of the low optimality demonstrator (both results are corrected for the regression-to-the-mean). There is no effect of the high(low) optimality demonstrator on the performance of the high(low) optimality participants. Importantly, the ability to better predict the behavior of high optimality demonstrator increases the optimality in phase 3, whereas the better ability to predict low optimality demonstrator does not influence the performance in phase 3. Conclusion. We find that observational learning in a stochastic environment can be both beneficial and detrimental. Low optimality participants, who are able to understand how high optimality demonstrator chooses, increase their performance, while the observation of noisy choices of low optimality demonstrator disrupts the performance of high optimality participants. These results suggest that in stochastic environments participants are influenced by the behavior dissimilar to their own.

J. Choice & Choice Mechanisms

2-J-40 Crowdsourced science: Analyzing variability in data analysis in neuroscience

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Trust in scientific knowledge comes from the ability to replicate empirical findings. However, the recent "replication crisis" in many sciences calls into question previously published results. A large share of false positive results can be caused by the many "researcher degrees of freedom" where results can be "trimmed" towards desired outcomes in the data analysis process. Recently, an attempt by Silberzahn and Uhlmann (2015) investigated how different teams of researchers arrive at different conclusions about the same data set in psychology. Similarly, in neuroscience there is an increasing debate about low statistical power and interpretational problems of fMRI data where researchers have some "freedom" in searching (intentionally or sub-consciously) for desired results. In our study we aim to provide the first scientific evidence on the magnitude of variability of results across analysis teams in neuroscience. In particular, we collected fMRI data from n=110 participants on two versions of the mixed gambles task (Tom et al, 2007). On each trial, a mixed gamble was presented (one gain amount, one loss amount) and the participants decided to accept the gamble or not. Each participant performed one of two conditions: In the equal indifference condition, the matrix of gambles included potential gains twice the range of potential losses (Tom et al., 2007); in the equal range condition, the matrix included an equal range of potential gains and losses (De Martino et al., 2010). For the data analysis process we aim to recruit around 30-40 research groups in neuroscience. These groups will be given the raw data to independently estimate the brain activations according to ex ante hypothesized brain regions. We predict activations in several regions for specific contrasts, based on previous results (Tom et al., 2007; DeMartino et al., 2010) and analysis teams will freely analyze the dataset to answer the hypotheses. The main outcome variables will be the number of teams reporting a significant result and the variation in brain activations across teams. Finally, we will measure peer beliefs about the main outcome variables by running prediction markets. Similar to our previous studies (Camerer et al., 2016, 2018) experimental subjects (recruited among researchers in neuroscience that are not part of the analysis teams) will trade on the outcome of our hypotheses. We will run 2 prediction markets for each hypothesis: (i) the fraction of teams reporting

significant results and (ii) the variability of analysis results across teams. Trading on the prediction markets will be incentivized. The goal of this abstract is to recruit the analysis teams.

2-J-41 Disadvantageous decision-making in methamphetamine users: loss aversion and dopamine D2/D3 receptor availability

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Most people tend to display an aversion to loss. This phenomenon has been demonstrated using economic choice tasks in which selections are made between choices that involve potential losses and gains. Theories of decision-making assume that individuals compute the value of each option by transforming components of the choice (e.g., magnitude and probability of potential gain or loss) into subjectively equivalent quantities that can then be integrated and compared. When an option involves a cost, such as the potential to lose money, the value of the reward is discounted as a function of the loss. The degree to which loss contributes to the discounting of subjective value shows individual variation, which can be measured by modeling individual choice parameters that can then be related to markers of neural function. The context of reward-based choices that present potential losses is particularly relevant to individuals with addictive disorders, for whom maladaptive decision-making contributes to the vulnerability to and persistence of their disorders. Despite behavioral and neural studies of loss sensitivity in addictions, analysis of individual choice parameters to distinguish the nature of differences between healthy and more biased decision-making has not been assessed in individuals with Methamphetamine Use Disorder (MUD). Moreover, loss aversion is modulated by brain regions associated with dopamine function, which is dysregulated in addiction, yet the relationship between measures of dopamine function and loss aversion has not been directly assessed. Therefore, we aimed to determine whether dopamine function is related to individual differences in loss aversion. Individuals with MUD (n=19) and healthy controls (n=24), matched for age and sex, completed a standardized Loss Aversion Task where they were shown gambles offering a 50% chance of winning or losing different amounts of money, or the option to opt out and accept $5 for sure (e.g., 50% chance of winning $10, 50% chance of losing $8; accept $5 for sure). Participants also underwent positron emission tomography (PET) with [18F]fallypride to assess dopamine D2/D3 receptor (DRD2/3) binding potential (BPND). MUD participants were significantly more loss averse than healthy controls ($p=0.01$), in contrast to the prevailing view that loss aversion is lower in individuals with addictions. Loss aversion was negatively correlated with DRD2/3 BPND in the nucleus accumbens of healthy controls ($p<0.05$) but not in MUD participants, suggesting a role for dopamine function in sensitivity to loss that may be dysregulated in MUD.

2-J-42 Gender differences in optimism biases during ambiguous decision-making

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Decision-makers are often faced with uncertain situations in which they have incomplete information. While risky decisions include information about the probabilities of the possible outcomes, ambiguous ones involve uncertain (or unknown) probabilities as well as uncertain outcomes. Prior work has suggested there are differences in how men and women evaluate risk, but evidence related to gender and ambiguity is mixed. Here, we examine whether there are differences in how men and women use valenced information to estimate value in ambiguous decisions. In the "Pro/Con" task (Peysakhovich & Karmarkar, 2015), participants indicate their willingness to pay (WTP) for "tickets" for several independent gambles, each representing a poker chip being randomly drawn from a bag of exactly 100

red and blue chips. The true color composition of the bag differs on each trial; participants receive partial information about the amount of red chips and blue chips it contains. A red chip draw results in a monetary payout; a blue chip results in no payout. Thus the number of red chips revealed represents the amount of favorable information while the number of blue chips revealed represents the amount of unfavorable information. Across analyses of pre-existing Pro/Con data and new experiments, we replicate the finding that favorable information (e.g. the number of red chips) influences WTP for the gambles more than unfavorable information (Peysakhovich & Karmarkar 2015, Buckholtz et al. 2017). Notably, we also find a consistent interaction between gender and favorable information such that individuals who identify as men show an enhanced bias towards favorable information. To better understand mechanisms underlying this optimism bias, participants (n=166, 104M) were asked to estimate the likelihood of a red chip being drawn, and their certainty about that estimate (in addition to WTP for the gamble). We model the effects of these subjective descriptions of perceived risk and ambiguity on WTP and find that men's risk estimates impact WTP significantly more than women's (β=. 567, p<.01). There were no differences in certainty/ambiguity related to gender. Modeling the impact of valenced information and gender on risk showed that men's estimates of the likelihood of winning were more pessimistic overall, but decreased less as unfavorable information increased (β=.0085, p<.001). Collectively, our studies demonstrate an enhanced "optimism bias" in how men use information in ambiguous settings. However, this bias appears to arise from differences in how information is used to estimate risk in these contexts, rather than how it impacts perceptions of ambiguity.

2-J-43 Influence of observation on other-regarding attitude: A computational exploration

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Study aims. Observing others' choices allows people to learn useful information about the social context and can potentially change their preferences. We investigate how other-regarding attitudes shift after participants are asked to predict the interpersonal choices made by others. We hypothesize that acquaintance with social choices of a group should push individual attitude towards them. We also test how two cognitive models of preferences are able to accommodate the shift in social attitude. The Preference Temperature model assumes that preferences are stable but are implemented with noise. The Preference Uncertainty model states that preferences are expressed without noise but change continuously gravitating towards a particular state. Methodology. 98 participants chose repeatedly in a task in which they could reduce their own earnings in order to increase or reduce earnings of an unknown other. Between the first and second parts of the task, participants made a series of predictions about the choices made in the same task by a group of previous participants. This observed group consisted of individuals who expressed an attitude similar to that of the participant but extreme (e.g., very altruistic or very spiteful). We estimated the two models of participants' attitudes before and after the manipulation using Markov Chain Monte Carlo estimation. Findings. Participants' attitudes shifted in the direction of the attitude expressed by the observed group. Notably, this effect was driven by altruistic participants, whereas spiteful participants appeared not to be consistently affected by observation. The size of the shift was the same irrespective of how distant participants' attitudes were from the observed group's and of how consistent participants were in their choices. Contrary to previous findings, when comparing the cognitive models, we found that the Preference Temperature model accounted for the shift in attitude better than the Preference Uncertainty model. Conclusions. Attitude towards other individuals appears to be influenced by learning about others' behavior. However, this effect is different for altruistic and spiteful people. This difference could imply that these two types of participants draw upon qualitatively different cognitive mechanisms. The Preference Temperature

model, which explains our data better, yields testable predictions about brain activation: value representation areas, such as the ventromedial prefrontal cortex and ventral striatum, should display a stable signal in absence of information about other's choices, whereas any influence of observation should produce clearly detectable changes in activation.

2-J-44 Greed personality predicts loss aversion through the neural activity in mOFC

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Background: Greed is commonly referred to as the tendency to constantly want 'more' and never being satisfied with what one currently has (measured by the Dispositional Greed Scale). Anecdotal evidence about the interaction between greed personality trait and economic decision-making abound but empirical neural evidence regarding how such interaction occurs is still lacking. In a risky decision environment, such greed tendency might manifest as subjects' risk attitude, loss sensitivity or both. In this study, we aimed to examine the impact of greed personality trait (GPT) while subjects engaged in a risky decision-making task. Methods: Twenty-five participants underwent functional magnetic resonance imaging (fMRI) while playing gain, loss and mixed gambles. All the participants also completed the Dispositional Greed Scale outside the scanner. Results: Behaviorally, we observed a significant negative correlation between GPT and loss aversion after controlling confounding covariates such as impulsivity but no correlation with individual risk attitude. The parametric analysis in fMRI data identified that individual difference in behavioral loss aversion is associated with brain activity representing neural loss aversion signal in the median orbitofrontal cortex (mOFC). Interestingly, GPT is also correlated with mOFC activity. Furthermore, mOFC activity mediates the correlation GPT and behavioral loss aversion. Conclusions: Our findings provided empirical evidence for the potentially role of OFC in the integration of gains and losses. More importantly, our results also pinpointed a specific role that GPT may be influencing risky decision-making via moderating loss aversion.

2-J-45 Sweat the context: How affect relates to contextual influences on risky decision-making

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Affect is related to risky decision-making, but recent evidence that temporal context influences risk-taking leaves two critical questions unanswered: what computational processes underlie the influence of temporal context, and what role affect may play in this influence. One possible underlying computational process is normalization, in which recent events shape expectations to which current values are compared. Consistent with a role for expectations, we found effects of recent events in the meta-analysis of a powerful, cross-study risky choice dataset in which prior positive outcomes decreased risk-taking and prior negative outcomes increased risk-taking. This established that choices reflected not just the value of current options, but those of recent events. To replicate this effect and extend these findings to the domain of affect, we collected skin conductance responses (SCRs) as a measure of arousal while participants completed a risky monetary choice task in which they chose between risky gambles with large possible rewards and smaller, safe options. To allow us to shift expectations over time and thus detect normalization in behavior, choice option values had a novel intentional temporal structure across the task. Preliminary data (N=27) replicated our meta-analysis, finding a negative relationship between previous outcomes and subsequent risk-taking (ß=-.02 (.006), p=.0001). We then examined to what extent SCRs were also affected by temporal context and related to behavior. For the subset of participants who consistently had non-zero SCRs to task events (N=18), linear mixed effects modeling found that temporal context influenced arousal: SCRs at the time of outcome increased as the absolute difference between the previous and current outcomes increased (ß=.04(.02), p=.03), akin to an

unsigned error term. This suggests that arousal may represent inaccuracy in expectations, a signal which could then gate the updating of those expectations. To test this possibility, we entered SCRs as a regressor in generalized linear mixed effects models of choice behavior. SCRs interacted with previous outcomes to potentiate their negative effect on choices (ß=-1.4 (.5), p=.009), consistent with a gating mechanism. While big previous outcomes decreased subsequent gambling, the same outcomes had a stronger effect on choices when SCRs were also large. Our novel findings not only demonstrate that risky decision-making is dynamic, but suggest a possible critical role for an affective mechanism in linking recent events to behavior, and more broadly provide evidence of temporal normalization in risky choice.

2-J-46 Why do decision makers reject low-stake positive-expected-value gambles?

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Decision makers often reject low-stake positive-expected-value gambles offering equal probabilities of a larger gain and a smaller loss. This behavior has been traditionally attributed to loss aversion, a psychological mechanism according to which losses are given higher utility weights than gains (Kahneman & Tversky, 1979; Rabin 2000). For this reason, rejection rates in low-stake positive-EV gambles have been used as behavioral measures to identify the neural correlates of loss aversion (e.g. Canessa et al., 2013; Chib et al., 2012; Frydman et al., 2011; Sokol-Hessner et al., 2009, 2013, 2014; Tom et al., 2007). In this paper, we consider two additional psychological mechanisms that could generate high rejection rates in such gambles: 1. A response bias towards rejecting gambles without the calculation of utility, and 2. An evaluation bias according to which gambles receive a constant additive penalty in utility. Using a drift diffusion model of decision making (Busemeyer & Townsend, 1993; Krajbich et al., 2010; Ratcliff, 1978), applied to choice and reaction time data from four experiments (including one incentivized and preregistered experiment), we are able to disentangle and quantify the effects of these three distinct mechanisms. Although all three mechanisms play an explanatory role, the response bias mechanism provides the largest quantitative contribution to individual and group-level model fits. This mechanism also predicts qualitatively unique reaction time patterns for acceptance and rejection responses, and we find support for these predictions in our data. Our results indicate that high rejection rates for low-stake positive-EV gambles can be a result of multiple different psychological mechanisms, and that a response bias applied prior to the computation of utility (rather than loss aversion) is the primary determinant of this behavioral tendency. These results have implications for how we interpret neural data in common risky choice tasks. They also illustrate the value of the drift diffusion model --a prominent neurocomputational theory of binary choice-- for quantifying and testing the psychological underpinnings of risky decision making.

K. Social Rewards & Social Preferences

2-K-47 Is talk cheap? Experimental evidence for strategic pragmatics in bargaining games

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The use of pragmatic (i.e., context-dependent and non-compositional language) strategies such as politeness is considered cognitively costly for both speaker and listener. However, these strategies are well suited to deliver information in ways that mitigate social burden between speakers. The use of pragmatic strategies is well documented, but little is known about how such strategies are utilized to maximize the probability of a specific behavioral outcome within an economic exchange, such as bargaining. To understand the extent to which communicators use politeness as a meta-cognitive strategy in sending selfish messages, we employed a deception game wherein participants were to send

messages to their counterparts about payoff options. 316 MTurk workers (46% female; all native English speakers) completed one of four conditions. Across all conditions, the Sender is told that payoff information is known only to her and that the Receiver remains ignorant of payoffs. The Sender must send a message to the Receiver, who the Sender believes will decide which option to choose. Knowing that the Receiver does not know the true state of the world, the Sender may suggest one of the two options, wherein both options detail a possible payoff outcome that is imbalanced in some manner (favoring either Sender or Receiver). In conditions 1 and 2, the Sender may only generate messages from a predetermined list of words, including the payoff options (i.e. "Option 1" or "Option 2") and either politeness terms or filler words with neutral valence. In conditions 3 and 4, the Sender is presented with a forced choice between a selfish and altruistic message that is either polite (Cond. 3, "Please choose Option 1") or neutral (Cond. 4, "Choose Option 1"). We hypothesized that Senders were most likely to be selfish when given the chance to be polite. However, our results were mixed: when being polite of their own accord (Cond. 1), Senders were most likely to be selfish (0.789 of trials). When message options were always polite (Cond. 3), Senders were least likely to be selfish (0.687 of trials). Our results may suggest that, when forced to be polite, message senders may feel beholden to other positive social norms, such as altruism. Contrarily, when given the freedom to use politeness or not, senders may feel the autonomous use of social language norms frees them from being bound to other altruistic behavior. Forthcoming work will focus on 1) the extent to which speakers are willing to pay to follow communicative norms (i.e. politeness) if their proposition is selfish, and 2) whether and how sociopragmatic strategies are realized in real-time bargaining interactions.

2-K-49 Flexibly integrating contextual inequality in fairness decisions

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Objective Receiving a small gift from an economically less fortunate other can be interpreted as a generous gesture, while receiving the same magnitude of gift from a wealthy other could even be offensive. Thus, adhering to the social norm of equity requires us to flexibly adapt our expectations and behaviors across different contexts. Studies investigating social norms are typically set in an equal setting, however, we are often faced with unequal contexts in everyday life. Here, we investigate the behavioral and neural mechanisms that allow for the integration of contextual inequality into decisions about fairness. Methods While undergoing fMRI, participants (N = 44) played 198 one shot Ultimatum Games (UG) with distributors who played previously. Across three blocks, participants were endowed with either ?1.90, ?7.50 or ?30.00 (Participant Endowment, PE). In each block, they interacted with game partners who had been endowed with either ?1.90, ?7.50 or ?30.00 (Other Endowment OE). In each interaction, the participant received a set of fair (?4, ?5, ?6) and unfair (?1, ?2, ?3) offers from their game partner from a ?10 pot, and could choose to either accept or reject the offers. Both before and after the scanning session participants indicated their expectation as to what each game partner would do. Results When participants received ?30.00, they accepted more unfairness from others with ?1.90 (M = 85%) and ?7.50 endowments (M = 77%) than from others with ?30.00 endowments (M = 36%, p <.001). Participants distinguished less between the EO conditions when they received ?1.90 (p=.030); they accepted less unfair offers from others with higher endowments (M(OE = ?1.90) =42% , M(OE = ?7.50) =40% , M(OE = ?30.00) =30%, p<.001). Moreover, participants in the ?1.90 condition accepted less fair offers from others with a ?30.00 endowment (M = 89%) than in the ?7.50 (M = 92%) and ?1.90 (M = 97%, p=.001) condition. Participants had higher expectations of others with higher endowments when they received lower endowments themselves (p<.001) and expected hyper-fairness M(PE = ?1.9, OE = ? 30.00) = ?5.90). Conclusion: This study demonstrates that participants flexibly adapt their behavior and

expectations according to different (un)equal contexts. Behavioral data showed that dependent on inequality between players, reaction to low offers is very different. Our interpretation is that low offers can be considered both fair and unfair; a low offer from a person with a low endowment to a person with high endowment actually decreases inequality. This will help us characterizing the different underlying neurological mechanisms of processing unfairness.

2-K-50 Integration of social information and value by superior temporal sulcus (STS) neurons in monkeys trading in a simulated stock market

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Investors in financial markets often exhibit systematic biases, such as 'herding', that can lead to overvaluation of share prices and 'bubble' markets. While humans have evolved Theory of Mind (ToM) as an essential tool for navigating complex social environments, ToM becomes maladaptive when used to forecast others' value estimations of stock prices (De Martino, et al. 2013). In order to further explore the evolutionary roots and neural circuit mechanisms underlying these behaviors, we developed a rudimentary 'stock market' task for rhesus macaques (Macaca mulatta), which was also validated in humans. We hypothesized a role for brain areas engaged in strategic social decision making (specifically, the temporal parietal junction; TPJ) in biasing value estimations when choosing actions in social vs. non-social contexts. Current work in our lab demonstrates that macaque middle superior temporal sulcus (mSTS), the putative homolog of human TPJ, is engaged during strategic social decision making, highlighting a potential role for STS in our task. Multichannel electrodes recorded electrophysiological activity from mSTS while monkeys (N=3) made investment decisions on a touchscreen computer for juice reward in 4 conditions: 1) computer opponent, 2) replay opponent, 3) decoy opponent, and 4) live opponent. Preliminary results indicate that monkeys and humans increase 'herding' behavior in the social condition, and that macaque mSTS neurons differentially signal the value of actions in social and non-social contexts. Furthermore, we observed an overall increase in engagement of mSTS neurons during the formation of bubble markets compared to non-bubble markets. This research suggests that mSTS neurons encode a social information signal that is likely integrated into downstream valuation computations (e.g. in vmPFC). Ultimately, the spontaneous inclusion of social information signals, which is helpful in most social situations, leads to suboptimal decisions in bubble markets.

2-K-51 Neuromodulation of other-regarding preferences via HD-tDCS over the right temporoparietal junction

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Objective: The structure and function of the right temporoparietal junction (rTPJ) have been associated with both social behavior and also with sensory integration, information processing, and attention allocation. We examine the effect of neuromodulation of rTPJ on other-regarding preferences and rational choice using focal high definition transcranial Direct Current Stimulation (HD-tDCS). We hypothesized that anodal rTPJ stimulation would cause participants to behave more altruistically relative to sham stimulation, and that cathodal rTPJ stimulation would have the opposite effect. We sought to measure the effect of stimulation on both social preferences and also on the consistency and rationality of individuals' choices. Methods: We applied anodal, cathodal, or sham HD-tDCS over the rTPJ (CP6) to 75 healthy participants during a charitable giving task where participants allocated an endowment of money between themselves and a local food bank. Participants chose allocations either on or under a graphical representation of a budget line. The endowment and the relative price of contributing to the charity were randomly varied across 50 independent trials. Participants and the charity were paid

according to one randomly selected decision. We fit each individual's choice data with a parametric utility function that measures the extent of other regarding behavior. We identify choice consistency and economic rationality with simple maximization errors (distance from the budget line) and with violations of the Weak Axiom of Revealed Preference (WARP) and the Generalized Axiom of Revealed Preference (GARP). Results: The parametric utility function indicates that individuals are more selfish with the cathodal treatment, and less selfish with the anodal treatment, relative to sham. We also find that budget maximization errors and WARP and GARP violations are more frequent with cathodal stimulation and less frequent with anodal stimulation relative to sham. Conclusion: Consistent with prior studies we find that rTPJ plays an important role in social behavior: HD-tDCS stimulation over rTPJ modulates other-regarding preferences. We also find that behavior was less rational in the cathodal condition, and more rational in the anodal condition, relative to sham. Thus we conclude that rTPJ plays a role not only in other-regarding behavior but also that rTPJ activity more broadly affects the consistency and rationality of choices. The results suggest that comprehensive theories of rTPJ function in social behavior should account for the multifaceted role that rTPJ plays in processing sensory information.

2-K-52 From trust in groups to trust in individuals

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Objective: Trust is ubiquitous in social interaction and recent work has begun to investigate how we learn to trust other individuals by tracking their average trustworthiness using basic learning mechanisms. However, our social world is structured by group information and little is known about how such information affects, if at all, decisions to trust. Here we investigated how we learn to trust and distrust individuals based on initial group membership and repeated interactions and aim to give a reinforcement learning account of this process. Methods: Participants (N=74) took part in a two-part experiment consisting of incentivized trust games. During the first part, the group phase, participants played multiple games with partners drawn from two groups identifiable by their t-shirt color learning the characteristics of the group as they played. One group reciprocated trust often (75%) and the other seldom (25%). In the second part, the character phase, participants played repeated trust games with four novel partners, two from each group. Two of the partners behaved as expected given their group membership and two behaved as a member of the opposite group. Participants also gave trustworthiness ratings of individuals and groups. Results: Participants readily learned to differentiate the groups in the initial group phase. In the character phase participants quickly adjusted to partners' actual behavior irrespective of group membership but were highly trusting on the first interaction with each partner. We fit a hybrid Pearce-Hall/Rescorla-Wagner reinforcement learning model to the data from both phases. The model could account for trial-by-trial data in both phases, and the model's fitted estimates of how trustworthy groups and individuals were correlated highly with participants ratings of trustworthiness from the end of the experiment. The best fitting model across featured larger learning rates for losses than gains, indicating that it is easier to learn to distrust than to trust over repeated interactions. The winning model also discounted prior learning when facing novel individuals. The per participant level of the discount parameter correlated with how well they learned to trust partners who came from untrustworthy groups but turned out to be trustworthy. Discussion: Our study provides a single learning account for how we learn and transfer trust in groups to trust in individuals. People readily learn and use group information for one-shot interactions, but heavily discount this during repeated interactions. Instead they adopt a strategy which assumes and initial risk of trusting and then quickly updates when trust is misplaced.

L. Risk & Uncertainty

2-L-53 The neural underpinning of bundle valuations for gains and losses under risk and riskless

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Early neoclassical economic theories mainly focused on indifference curves to explain riskless consumer choice between available bundles of goods. One critical observation of this research is that, for most of goods, indifference curves are convex. In this study, we aim to: 1) predict the shape of indifference curves under three currently dominant theories of choice: expected utility theory, prospect theory and the Koszegi and Rabin (2006) model, 2) experimentally verify these behavioral predictions, and 3) characterize the neural signature of bundle valuation for gains and losses, in risky and riskless choice. Arrow and Enthoven (1961) established that the shape of indifference curves depends on the first and second derivatives of the utility function with respect to each good, and on the mixed derivatives of utility function. Since Von Neumann and Morgenstern (1944) introduced expected utility theory, utility curvature and risk preference have been widely studied. Behaviorally, much data has shown diminishing marginal utility (risk-aversion) for probabilistic gains. Intriguingly, if we impose minimal restrictions on the mixed derivate, expected utility theory predicts convex indifference curves for both gains and losses. On the other hand, Kahneman and Tversky's prospect theory with a reference point separating diminishing marginal utility for gains from increasing marginal utility for losses predicts convex indifference curves in the gain domain but concave indifference curves in the loss domain. Paradoxically, such indifference curves imply that consumer would prefer losing all of one type of good to losing some of each of the goods in a bundle. We empirically measured utility under risky choice and indifference curves under riskless choice using incentive-compatible. The same participants completed both tasks with the same two consumer goods in both the gain and loss domains. Behavioral data shows that when one shifts from gain to loss domain, the utility curvature measured under risk changes as predicted by prospect theory but indifference curves remain convex across gain and loss domain, which contradicts prospect theory (in the riskless domain). None of the models that we examined can adequately explain both behavioral results. Neuroscientific data have identified utility representations in brain areas including ventral striatum, orbital frontal cortex, and posterior parietal cortex. Ongoing imaging of 30 subjects should allow us to describe similarities and differences in neural representation of the value of bundles in different contexts.

2-L-54 Decision process improvement based on behavioral experiments of multi-attribute choices with graphical visualization

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Multi-attribute decision making considers preferences of DMs (Decision Makers) in a quite complex situation. In this kind of decision process in order to handle with their preferences, a large cognitive effort is demanded from DM. Objective: This study aims to explore the potential of using visualization in Multi-attribute choices, considering a Decision Support System (DSS) related to FITradeoff method. This kind of visualization abbreviates the elicitation process, reducing the cognitive efforts. Method: A structured set of tables and graphical represent the visualization in the DSS for FITradeoff method, working in the context of Multi-Attribute Value Theory (MAVT). The graphical and tables has variation in the number of items (combining alternatives and attributes, both between three and five) with two different patterns of criteria weights (equal and different values). While undergoing EEG and eye tracking, fifty three subjects analyzed this visualization set. The subject was asked to choose the best alternative, so HR (Hit Rate) can be evaluated, associating with EEG and the eye-track conditions. Results:

Based on the combined results of the EEG and eye-tracking experiment, suggestions are made in order to improve the design of the DSS and also to give insights to the analyst, when interacting with the DM. In a pilot test three different sequences of graphical have been applied: with increasing, decreasing, and random order of difficulty. The results have shown that the HR is rather higher for the sequence with random difficulty, which has been chosen to be applied. Several results can be shown, such as those following mentioned. Conditions and factors associated with better HR whether in tables or graphics. The HR of graphical visualization is not correlated with the total number of items, including attributes and alternatives. It seems these two items are processed in different ways. For instance, the HR for 8 items is 33% or 75%, respectively with 3x5 (alternatives x attribute) and 5x3. Based on AOI analysis, it has been observed that attribute with higher weights placed in left-central positions have highest Fixation Duration. The HR has been associated with different conditions, such as fixation region, pupil diameter, pattern of criteria weights, processing time, channel and other parameters in EEG, and so forth. Conclusion: Results are being applied in the improvement of the design of the DSS for FITradeoff method and obtaining insights that analyst can use when interacting with the DM. Also, directions for further analysis in MAVT context are obtained.

2-L-55 The automatic evaluation of price: An EEG study

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Objective: People encounter numerous price stimuli on a daily basis. It is assumed that these stimuli are evaluated instantaneously, and that this evaluation has a profound impact on the eventual purchase decision. This automatic evaluation is believed to result from comparing the actual price with the subjective reference price, which is built out of previous encounters with the product and its corresponding price. Past studies used event-related potentials (ERPs) to investigate how price stimuli are evaluated and how these ERPs can be used the predict future purchase decisions or product evaluations. Yet, these studies were conducted within a transactional context and therefore it is difficult to isolate automatic evaluation from more complex purchase-related processes. Here, we were interested in the automatically evaluation of price stimuli in absence of immediate purchase intentions. We anticipated that the N200-P300 complex would play an important role in this process, since it was repeatedly shown to reflect feedback related and evaluative processes. Also, we were interested in late positive potentials (LPPs), which is known to reflect the initial appraisal of (emotional) stimuli. Our hypothesis was that these ERP components will vary as a function of how much the observed price deviates from the internal reference. Method: Participants (n=36) had to merely observe a number of regular household Products shortly followed by a price stimulus. When the price stimulus disappeared, instructions appeared on the computer screen. Either participants had to press the spacebar as fast as possible or evaluate the price as 'cheap' or 'expensive' by pressing the corresponding key. ERPs were recorded time-locked to the presentation of the price stimulus. Crucially, we manipulated the magnitude of the price stimuli: price stimuli could be 10%, 40% or 70% higher (or lower) than the current retail price of the product. Finally, participants had to complete the PERVAL survey for all products used during the experiment. This allowed us to relate the measured ERPs to the explicit evaluation of the product-price combinations.Results: Our findings show that both the N200 and the LPPs are sensitive to the price manipulations. In particular, very cheap prices (i.e. 70% cheaper than the current retail price) evoke the strongest ERPs. Both the N200 component and the LPPs gradually increase in line with the magnitude of the price stimulus. However, the effect was less clear for the unambiguously cheap prices. These preliminary findings suggest that ERPs can be useful to study valuation by the mere observation of a price stimulus.

2-L-56 Deep-EEG: Decoding valuations from neural activity to predict consumer preferences

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The properties of EEG datasets raise difficulties for conventional machine learning and regression methods, when trying to perform predictions based on these datasets. These difficulties arise mainly because of small data sets, the need for elaborate and exploratory feature extraction, and the intrinsic noise and obscurity of the signal. Our aim is to try and overcome these limitations using Deep Learning Networks (DLNs) models. DLNs have revolutionized many research fields, such as Computer Vision, Brain-Computer Interfaces (BCI), Artificial Intelligence and more, and has already shown success utilizing EEG signals. In this study, we apply a DLN model to overcome the drawbacks of EEG datasets and perform predictions of subject-specific value preferences. Using DLNs would alleviate the need to manually search for specific features in the EEG signals that contain value information, but instead the model would identify predictive features on its own. A comprehensive network could also contain elements that are able to disregard noise and enhance the signal. Our experiment consisted of 72 products from 6 different categories, that subjects viewed 3 times per product. Each subject was first presented with a product's image together with its short description. This was followed with a standard BDM task (Becker DeGroot and Marschak, 1964), by presenting a sliding bar with which the subject could indicate the maximal amount she was willing to pay for the product. We recorded subjects' EEG data throughout the experiment. Then we use segments of EEG data from product observation to predict the corresponding reported BDM values, after we transform the segments to "Activity Maps", which consider the spectrogram and electrode space. So far, we have recorded data from 40 subjects. Yet, because these prediction models require large datasets, we plan to recruit at least 300 hundred subjects. We propose a novel DLN architecture that considers the unique characteristics of the EEG signal and offers three types of normalization to account for the signals' dependencies: by-subject, by-trial, and by-period. Our interim prediction results vary in their success but suggest that deep learning methodologies may be the superior way to perform EEG-based predictions, due to its ability to consider multiple dependencies, improve SNR, and eliminate manual feature extraction by automatically identifying optimal value-related information. Visualizations of the first layers of our network offers insight into the process with which its decodes the EEG signal to obtain valuations, possibly shedding light on the most predictive features of the signal and the neural mechanisms involved.

2-L-57 Neural mechanisms underlying effortful persistence

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The adaptive adjustment of behavior in pursuit of desired goals is critical for survival. To accomplish this complex feat, individuals must weigh the potential benefits of a given course of action (e.g., food, safety from predators) against time, energy, and resource costs. Prior work in this domain has greatly advanced understanding of the cortico-striatal circuits that support motivated goal pursuit, characterizing core aspects of subjective valuation. However, these complex dynamic calculations have traditionally been examined at discrete points, for instance evaluation and choice. How information about time and effort costs are integrated in valuation is less well understood. When persistence has been examined, it has primarily been limited to the temporal domain, leaving the mechanisms underlying individual differences in the dynamic updating of effort requirements during goal pursuit poorly understood. Utilizing tasks that better map onto the dynamic nature of naturalistic goal pursuit may allow us to characterize the neural mechanisms underlying variable success in goal achievement across individuals and contexts. In the present ongoing study, participants underwent functional MRI (fMRI) while completing a novel

paradigm to examine willingness to exert physical effort to obtain monetary rewards or avoid punishments. Preliminary results indicate that effortful exertion in pursuit of obtaining reward or avoiding punishment is recruiting a broad network of cortico-striatal and cognitive control regions, including ventromedial prefrontal cortex and dorsomedial prefrontal cortex. Ongoing analyses aim to fit computational models of effort expenditure and analyze fMRI data for ramp-like signals that are modulated by physical effort expenditure. By revealing how willingness to exert physical effort is instantiated and updated in the brain, the current study can inform how effort cost weighting impacts goal pursuit and achievement.

2-L-58 Representation of subjective value for self and other agents in the dorsal anterior cingulate cortex is consistent across tasks and predicts social attitudes

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While making decisions on behalf of others is ubiquitous in daily life, few studies have addressed the neural computations underlying this phenomenon. We investigated the neural correlates of value-based decision-making for both self and other in two independent behavioral tasks using fMRI. Behavioral paradigms included intertemporal choice (n = 20), in which participants chose between options of smaller amounts of money sooner or larger amounts of money later, and risk (n = 21), in which participants chose between options of smaller amounts of money with larger probabilities or larger amounts of money with smaller probabilities. Behavioral modeling indicated that participants distinguished between themselves and other individuals with dissimilar preferences. We then calculated the difference in subjective value between options, defined here as relative subjective value. Dorsal anterior cingulate cortex (dACC) activity negatively correlated with relative subjective value, while ventromedial prefrontal cortex (vmPFC) activity positively correlated with relative subjective value ($P < 0.05$, corrected). Both effects were consistent in self and other trials and in both behavioral tasks. These results held even when including response time as a nuisance regressor to control for decision conflict. Neither area was found to respond to the absolute subjective value of the chosen option for either task, indicating that these areas likely code for a relative comparison between option values and not for the absolute value of the desired option. Multivoxel pattern analysis indicated that the dACC, but not the vmPFC, selectively decoded high versus low relative subjective value, and these results were again consistent across self and other and were replicated in both tasks ($P < 0.01$, permutation). Corresponding to univariate results, neither area decoded the absolute value of the chosen option. The code for relative subjective value in the dACC was generalizable across self and other, as classifiers trained on data from self trials were able to categorize value in other trials and vice versa ($P < 0.01$, permutation). Notably, this neural code in the dACC was even generalizable across tasks, as classifiers trained on data taken from the dACC during intertemporal choice were able to predict value in trials from the risk paradigm ($P < 0.01$, permutation). Finally, classification accuracy in other relative to self trials correlated with self-reported social attitudes ($P = 0.03$, Spearman). Together, these results indicate the importance of subjective value-related signals in the human dACC, arising during decision-making across different perspectives and contexts.

2-L-59 When the best options are not necessarily the most valuable: Reward versus goal congruency as determinants of choice value

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Objective: Research on value-based decision-making has demonstrated consistent behavioral and neural correlates of choice value, such as a choice set's overall value (OV) and the relative value (RV) of the

chosen (versus unchosen) option. However, these choice values have almost universally been tested under conditions where higher values are more consistent with the goal of choosing the most preferred option. It is therefore unclear to what degree past behavioral findings, such as the speeding effect of overall set value, are driven by reward per se (e.g., a Pavlovian effect) or goal congruency. It is similarly unknown whether neural correlates of RV and OV reflect their rewarding properties or their goal congruency. Here, we explicitly varied choice goal in order to tease apart relative contributions of goals and rewards to valuation and choice. Methods: Participants in a behavioral (N=30) and an fMRI (N=25) study viewed sets of four consumer products and, in separate blocks, were instructed to choose the best or the worst item out of the set. Choice sets were constructed to vary in OV and RV, based on subject-specific item ratings. Results: When choosing the best item, we replicated previous findings: RTs were faster with higher RV and OV, and both of these variables were positively encoded in an a priori valuation network (Bartra et al., 2013). When choosing the worst item, many of these effects reversed. Most notably, choices were now slower with OV and the valuation network now negatively tracked RV, consistent with a goal-congruency effect. We directly tested whether valuation network activity was better accounted for when RV and OV were determined by the reward value or the goal congruency of the options. We found that network activity increased with (a) RV based on goal congruency and not reward value (i.e., higher when choosing comparatively bad options in the choose-worst condition) and (b) OV based on both goal congruency and reward value. Conclusion: Our findings offer new insight into the influence of goals on the dynamics and mechanisms underlying value-based choice. First, they show that the typical speeding effect of OV on choice is a function of its ability to facilitate one's choice goal rather than its reward value, ruling out Pavlovian accounts of such findings. Second, they show that the brain's valuation system tracks choice values in terms of their goal-congruence, possibly in addition to their reward value (in the case of OV). Collectively, this work suggests that future decision-making research should account for the value choice options hold for the task at hand, separately from how much reward they promise.

2-L-60 No pain no gain: Neural correlates of decision-making about pain

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Pleasure and pain are nature's "two sovereign masters" that dictate our everyday decision-making. In the case of patients with chronic pain, it is not rare to see these two sources of motivation entering in conflict with one another, as rewarding activities often come at the price of increasing their pain. In order to make these difficult decisions, an abstract value representation of the anticipated pain has to be computed and compared against the value of the competing reward. In a first study, we aimed at determining the monetary value of pain in order to gain insight on how it influences reward seeking. The participants had to accept or decline offers that included pairs of varying levels of pain (threshold to tolerance) and monetary compensations. While the 16 monetary offers ranged linearly from $0 to $5 or $10 in Group1 and 2, respectively, they increased exponentially from $0 to $5 in Group3. Our data show that the monetary value of pain increases quadratically as a function of the anticipated pain intensity ($t=5.04$, $p<0.001$). Whereas doubling the monetary offers had no significant influence on the pain value (Group2-Group1), changing their distribution (Group3-Group1) significantly decreased it ($t=1.52$, $p=0.045$). The psychometric data show that harm avoidant personalities predict an increased pain valuation, whereas goal-directed mindsets are predictors of a devaluation of pain. In a second study, we conducted a brain imaging experiment to examine the cerebral mechanisms underlying 100 decisions about pain and money. Results show that medial prefrontal structures computed an abstract value representation common to both pain and money and were used to make decisions about pain.

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A. Attention

3-A-1 Physical salience and reward-value-based salience utilize different neural mechanisms to improve attentional selection of a visual search target

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Value-based salience describes how reward-associated stimuli can garner enhanced attentional selection. This occurs even when such stimuli are task-irrelevant, suggesting that this process is involuntary and mostly outside of top-down attentional control. There are two competing theories describing how value-based salience modulates attention. The first notes that value-based salience generates similar behavioral effects as other traditional modulators of bottom-up attention, like physical salience, and thus suggests that value-based salience must utilize the same neural mechanisms. Another theory argues that value-based salience falls outside the traditional explanations of attention and thus must utilize a different set of neural mechanisms, although they do not identify what these differences may be. We tested these ideas by independently modulating the physical-salience and value-based salience of targets within a visual search task while recording EEG/ERP measures, focusing on the attentional-orientation-sensitive ERP component N2pc. Participants (n=24) searched an array of ellipses for a color-singleton target and responded to its orientation. Targets came in three possible colors, one of which had high-physical salience (relative to the distractor ellipses), and two had low-physical salience. The task had three phases. For the first, baseline phase, no reward was offered. As expected, the high-physical-salience targets garnered greater attentional allocation, reflected by faster response times (RT)s and earlier N2pcs. The second, equal-reward phase added a small reward incentive for correct and sufficiently fast responses for all target types. This resulted in faster RTs and larger N2pcs for all target types relative to the baseline phase, but RTs and N2pc latencies for the high-physically salient target remained faster and earlier. In the last, selective-reward phase, one of the two low-physical salience targets was imbued with 10 times the reward value as the other two types. RTs for this target became as fast as that of the low-reward, high-physical-salience target. However, the N2pc onset latency was still significantly slower than for the high-physical-salience targets, instead showing a significantly larger amplitude. The independent relationships between N2pc onset to physical salience and N2pc amplitude to value-salience suggests that these different forms of salience utilize different neural mechanisms to modulate attentional selection, even if they can result in similar behavioral outcomes. Further characterization of these mechanisms may inform our understanding of the reciprocal interactions between attention and reward-processing.

B. Emotion & Affect

3-B-2 Sum before difference: ERPs reveal differential temporal contributions of overall set value and value difference

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Objective: Research in perceptual and value-based decision making alike has demonstrated that a centro-parietally distributed positive event-related potential (CPP) tracks the amount of evidence in support of a given choice option, until that evidence reaches a putative decision threshold and a response is made. However, the limited research into the dynamics of value-based choice has focused on relatively short decisions and often specifically on the dynamics associated with the relative subjective value of one option over another (value difference [VD]), and less on the overall value (OV) of a choice

set. However, behavioral findings highlight contributions of OV to decision dynamics. Indeed, supported by MEG findings, biophysically plausible models predict sequential neural effects of OV and VD. Yet it is unclear whether OV and VD effects reflect different stages of the same underlying process, or whether OV contributions reflect a more stimulus-related subprocess in value-based choice. Here we use EEG in a paradigm orthogonally manipulating OV and VD to examine their respective stimulus and response-locked contributions to value based decision making. Methods: We measured EEG while participants (N=39) made a series of choices between pairs of consumer goods that they had the opportunity to receive. Choices were individually tailored to vary in OV and VD (based on prior ratings of each item), and participants were given up to 4s to make each choice. EEG data were analyzed stimulus-, and response-locked, using a MASS-univariate approach with cluster-based permutation tests. Results: We found that OV and VD modulated event-related potentials (ERPs) with differential topographies and timing: whereas OV was associated with a CPP locked to stimulus onset (peaking 700ms post-onset, much earlier than most decisions were made, median RT=1.7s), VD was associated with a pronounced frontocentral negativity and posterior positivity locked to the response (peaking ~ 500 ms pre-response). The timing of the stimulus-locked CPP effect and the lack of a response-locked CPP - including when using RT as a proxy for evidence accumulation - challenge the claims that CPP reflects a signature of a supramodal decision variable. Conclusion: Our results are in line with certain biophysically-inspired computational models of decision-making that predict sequential encoding of OV and VD while suggesting that different patterns of brain activity might underlie the accumulation of additive value (OV) and relative value (VD).

3-B-3 Behavioral experiments associating calculus and video music listening activities with the decision process with multi-attribute context

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Multi-Attribute Decision Making problems are common in many professional and personal situations, representing a complex situation to be dealt with. The cognitive effort by Decision Makers (DMs) in order to express their preferences is one of most important issues for reducing inconsistencies in the process. Therefore, understand this process with neuroscience tools may contribute for the improvement of the decision making process in the scope of MAVT (Multi-attribute Value Theory). Objective: The aim of this study is to obtain more information with regard to the brain processes when comparing calculus and music listening activities and its association with the steps of a tradeoff preference elicitation procedure and graphical visualization. Method: A set of calculus activity were built in order to represent different decision situations when compared with an activity of listening and watching a video with a diversified set of music. Then, a subsequent a sequence of steps related to preference elicitation has been conducted. The preference elicitation procedure is implemented in a Decision Support System (DSS), with numerical and graphical information for comparing pair of outcomes. Also, a task for multi-attribute choice of alternatives based on numerical and graphical visualization has been conducted. A combined information of the EEG and eye-tracking experiment and also synchronized has been registered for comparing calculus activities with video music listening activities. Results: Based on the results of the EEG, it has been observed that the power intensity of Beta and Gama EEG channels are significantly different when comparing calculus activities with video music listening activities. Other channels did not present significant differences, although this has been observed in a few regions for Alfa channel. ANOVA tests have been applied and also, non-parametric tests Wilcoxon rank sum test with continuity correction have shown similar results. Conclusion: This results are intended to be applied for the improvement of

the DSS for preference elicitation with multi-attribute method in the scope of MAVT, using tradeoff procedure in order to enhancement the decision making process. Although, additional analysis are still being undertaking, it could be observed in which steps and kind of information has a brain processing pattern close to either pattern related to calculus or video music listening activities.

3-B-4 Distinct forms of salience differentially accelerate value-related decisions

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Objective Salience (defined as absolute value) is thought to accelerate value-related decisions. However, it is unclear whether this effect arises similarly in situations where the decisions are instrumental or inconsequential for obtaining and avoiding positively and negatively valued outcomes. Here we investigated two types of salience, elemental and global salience which differ when outcomes comprise both gains and losses. Global salience corresponds to the absolute expected value, whereas elemental salience sums up the absolute values of each element. Methods We have so far conducted a behavioral study in twenty healthy young participants, with current ongoing data collection. Geometric figures and colors were first associated with different monetary outcomes (+/-1 CHF, +/-5 CHF and +/- 10 CHF) during a learning phase. The learned colors and figures were subsequently combined and used in two different types of decisions. In instrumental decisions, participants either accepted or rejected the offered combination. If they accepted, then both gains and losses were implemented, if they rejected they did neither lose nor gain anything. In inconsequential decisions, participants judged whether the net outcome of the offer was larger than zero. Response times were measured for each trial, individual averages regressed against elemental or global salience and regression weights compared against zero (one-sample t-tests) or between decision types (paired t-tests). Results We found that elemental salience significantly accelerated both instrumental ($p=0.003$) and inconsequential ($p=0.002$) decisions. There was no significant difference in the accelerating effect of elemental salience between the two decision types ($p=0.841$). By contrast, global salience accelerated inconsequential decisions ($p=0.006$) but not instrumental ($p=0.704$) decisions. Moreover, the accelerating effect of global salience was stronger for inconsequential than instrumental decisions ($p=0.030$). Conclusion Our findings suggest that salience can facilitate value-based decisions. Interestingly, distinct forms of salience differentially affect behavior depending on whether or not outcomes are contingent on the behavior. The specific impact of global salience on decisions where outcomes are imposed may be of interest in clinical contexts.

3-B-5 How values change during sequential information sampling in multiple option choices

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When people make choices in real life, options do not present themselves simultaneously. Even if all options are side by side, as in supermarkets, decision makers can only pay attention to and valuate one option at a time. How such sequential sampling process affects option values is still poorly understood. Here, we build on two lines of research to propose a model of how sequential sampling affects the valuation process. First, it has been observed that items selected during binary choice benefit from an increase in value, as shown by likeability rating. Second, it has been suggested that a natural frame of comparison is opposing a default option to alternatives. We therefore hypothesized that during sequential sampling, every new option is covertly compared to the current default option. The option that wins this covert comparison then receives a fixed bonus in value and becomes the new default. Symmetrically, the value of the defeated option is diminished by the same extent. In this study, we tested this hypothesis by fitting model on choice behavior collected in a group of healthy participants (n

= 23). Options were items drawn from a same category (either food, magazine or DVD) and presented side by side on a computer screen. Prior to the choice task, participants rated the likeability of every item on a visual analog scale, in order to obtain subjective values that were used by computational models to predict choices. During information sampling, options were transiently unmasked one after the other, when participants pressed a key. The number of options varied from 3 to 6, such that the end of the sequence remained unpredictable in most cases. When all options had been seen subjects were prompted to make a choice, and to report their confidence that they had made the best choice (for their own sake). We used choice, confidence rating and response time data to compare our model (bonus by competition) to memory models with primacy or recency effects (bonus is given to items early or late in the sequence), as well as a pairwise pruning model, in addition to the null hypothesis (no change in value). All models predicted choice through a softmax function of option values. We compared the model-free results against model simulations. Group-level Bayesian model comparison favored our hypothesis (exceedance probability > 95%,) that values are changed depending on the outcome of a covert value comparison (between new and default options). These results extend the notion of cognitive dissonance to implicit binary choice, and more generally provide further evidence that the sequence of option sampling is not neutral for value-based decision-making.

3-B-6 Relating the attraction effect with the proximity effect in Gestalt

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Objective: The Gestalt law of proximity suggests that we tend to combine elements that are close to each other. Similarly, a well observed choice phenomenon is the influence of a (close) decoy option on the relative preference between two alternatives. Previous studies demonstrated that there are analogies and similarities between sensory, cognitive, and value-based processing. Therefore, we hypothesized that the value distance between a decoy and a target option would be conceptually analogous to the physical distance between objects as manifested in the Gestalt law of proximity. Methods:37 subjects performed two tasks. First, a psychophysical task which measures for each subject the threshold to differentiate between two stimuli of 12 dots arranged in a row, while the distance of the dots in one of the stimuli was systematically varied across trials. Second, a choice task which measures for each subject her tendency to be affected by the introduction of a decoy option to the choice set. In the basic condition, participants made choices between two gambles. In the decoy condition, we systematically varied the value distance (either the amount or the probability) between the decoy and the target. We then, related for each subject their sensitivity across both tasks. Results: Regarding the perceptual task, subjects showed a variation in their threshold to differentiate between the two stimuli. As for the value-based task, some of the subjects showed an increase in the preference for the target option after introducing the decoy option, demonstrating an attraction effect. On the other hand, some of the subjects showed the opposite effect: a decrease in the preference for the target option- a repulsion effect. We found that in a subset of these subjects (subjects who showed a consistent attraction effect, i.e. in several levels of value distances), the bigger the change in preferring the target option when moving from the basic to the decoy condition was, the lower the susceptibility to grouping by proximity was (i.e. it took a larger physical distance between the dots to differentiate between the two stimuli). However, there was no such correlation for the repulsion effect. Conclusions: The variation across subjects in their susceptibility to the Gestalt law of proximity might account for some of the variation observed in the attraction effect. We suggest that individuals who are less susceptible to grouping by proximity perceive choice options that are relatively similar in value as different (they do not

group them), and thus tend to concentrate on the dominance of one option over the other, which makes them more susceptible to the attraction effect.

3-B-7 The role of rat anterior cingulate cortex in effort-based choice probed by DREADDs and miniaturized fluorescence microscopy calcium imaging

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Effort is a cost that must often be overcome to procure rewards. Compared to the exploration of striatal mechanisms in effort-based choice, there have been relatively fewer studies of the cortical mechanisms in selecting between qualitatively different rewards (more preferred vs. less preferred). To explore this, Long-Evans rats were tested in a self-paced effort-based choice task where they could select between lever pressing on a progressive ratio schedule for sucrose pellets versus consuming freely available standard lab chow. We first sought to replicate effects of anterior cingulate cortex (ACC) lesions (Hart et al 2017) using a chemogenetic approach. Rats were infused with 0.5 uL of AAV8-CaMKIIa-hM4D(Gi)-mCherry in ACC to specifically target pyramidal neurons. Clozapine-N-Oxide (CNO, 3.0 mg/kg, i.p.) decreased lever pressing in the context of choice in the ACC group, compared to vehicle. Importantly, these effects were not due to inability to lever press, decreased appetite, or changes in food preference. We also found that CNO had no effects in a separate cohort of null virus-expressing (eGFP) control rats. Next, to track the dynamics of choice on a second-by-second basis, rats were infused with a virus containing the fluorescent protein GCaMP6f in ACC followed by implantation of a GRIN lens for endoscopic imaging. We recorded calcium transients using custom-made miniaturized fluorescence microscopes in ACC during choice testing to determine whether high effort and low effort choice are represented in differential neuronal ensembles. Our preliminary data indicate there are populations of task-engaged cells preferentially active during lever pressing, chow consumption, or both in ACC. Ongoing analyses of behavioral economic indices generated by fitting an exponential model (Hursh & Silberberg, 2008) to our data include measure of changes in demand intensity (Q0), essential value (EV), and demand elasticity (α) following either ACC lesion or chemogenetic inactivation.

3-B-8 Motivational control of mental effort allocation during decision-making

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Why do we think carefully about some decisions but not others? We propose that mental effort is strategically deployed--the amount of executive resources that a decision-maker allocates to a task is proportional to its expected value. We developed a computational model to demonstrate the mechanics of this process: a decision starts with a default assessment of option values, which is progressively refined through effort investment. Such effort increases the probability of making the right choice but carries a cost. The optimal effort allocation is the level at which marginal cost equals marginal benefit. A core driver of the benefit is decision difficulty (option value similarity). Difficult decisions start with a low probability of choosing correctly and thus induce a demand for resources. Our model predicts a non-trivial relationship between difficulty and effort, which depends on individual-specific cost and efficacy parameters. To validate our model, we conducted a behavioral experiment. Participants rated items, then chose between pairs of the items, then re-rated the items. In accordance with our model, the results show larger rating revisions, higher rating precision gain, and more "changes of mind" for difficult decisions, as well as for choices where item ratings were initially uncertain. Difficult or uncertain decisions were also slower, consistent with the idea that more time was needed to distinguish the items. The data also support the counter-intuitive model predictions that, controlling for difficulty, rating change correlates negatively with response time (RT) and positively with confidence. We conducted a

second experiment to demonstrate the effects of benefit and cost manipulations, and to illustrate how RT and pupil dilation (PD) capture orthogonal aspects of effort allocation. Participants performed the same task as above, now across three conditions: neutral, reward (effort incentive), and penalty (effort disincentive). We also predicted that PD would be greatest in the penalty condition--because we view effort as being composed of duration and intensity, we thought that penalizing duration would increase reliance on intensity (evidenced by PD). The results show that participants responded faster and had greater PD in the penalty condition. The data also show that half of the participants had both longer RT and larger PD for the reward versus neutral condition. In sum, our findings validate our model predictions in general, and also those specific to benefit and cost (though they suggest motivation differs across individuals). Our findings also support our use of RT and PD to jointly represent a measure of mental effort allocation.

3-B-9 Is cognitive effort painful? Investigating choices between physical pain and cognitive effort

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Study objective The expenditure of cognitive effort can be aversive and the decision to engage in effortful cognitive processing involves evaluating the costs and benefits of the action (Kurzban, Duckworth, Kable, & Myers, 2013). In fact, avoiding expenditure of effort is sometimes seen as more desirable than receiving monetary rewards (Westbrook, Kester, & Braver, 2013). This suggests that tied to cognitive effort is a motivational drive to escape actions that require excess expenditure of cognitive resources. However, the characteristics of such action remain unclear. How do the costs/benefits of cognitive effort avoidance change when paired with a primary incentive, such as pain avoidance, rather than a secondary incentive, such as monetary reward? Here we contrasted the aversiveness of cognitive effort with physical pain using a novel trade-off paradigm. Methods Thirty-one participants were offered a series of choices between different levels of painful thermal stimuli and different levels of cognitive load. Five different levels of the N-back working memory task (N = 0 to N = 4) were used as the cognitive load task. The level of cognitive effort required to perform the task increased parametrically with the level of cognitive load (Braver et al., 1997). For the painful thermal stimuli, five different temperatures were used to elicit a painful sensation (45 °C to 49 °C). Each temperature used was individually calibrated to equate the painful sensation across participants. At the start of each trial, the participant was shown a given level of each task and was asked to make a choice between the two. After a decision was made, the corresponding task was administered (i.e., either a painful thermal stimulus or several trials of the N-back task). Results Our findings indicated a trade-off between the level of cognitive effort required and the level of physical pain. That is, as the level of cognitive demand increased, participants were more likely to accept physical pain rather than expend cognitive effort, $F(4,120) = 45.40$, $p < .001$. Mirroring this, as the level of offered pain increased participants were less likely to accept physical pain and instead preferred to expend cognitive effort, $F(4,120) = 42.50$, $p < .001$. Conclusions Our findings highlight the aversive nature of cognitive effort. When paired with a primary aversive stimulus, such as pain, people will sometimes forego expending cognitive effort in exchange for pain. These results further our understanding of the mechanisms involved in expending cognitive effort and how avoidance may be similar to other primary avoidance incentives.

3-B-10 Counterfactual reasoning underlies the learning of priors in decision making

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Introduction. Accurate decision making relies on both evidence bearing on the choice at hand and prior knowledge about the statistical regularities bearing on the possible options. In some instances we learn

these regularities through education, but more often such knowledge is acquired over time through decisions we make ourselves. This poses a problem because absent an omniscient teacher, our decisions can be inaccurate, which limits our ability to update our beliefs. We hypothesized that in the absence of explicit feedback, decision confidence guides the acquisition of prior probability and does so in accordance with Bayesian updating. Methods. Three participants were presented with a dynamic display of random dots of variable duration and had to decide whether the net direction of motion was rightward or leftward. Within a block of 15 to 42 trials, one direction of motion was more likely, but which direction was more likely (and by how much) was unknown to the participant. The difficulty of the decision was controlled by three factors: strength of motion, stimulus duration, and bias strength (base rate). Participants knew the possible values the base rate could take, but were not told which one applied to the current block. Participants made three responses in each trial. They first reported the perceived direction of motion and the confidence that this decision was correct. They then reported whether they considered the block to have a right or left bias, and the confidence in this judgment (termed 'belief'). Participants received no feedback about the accuracy of their decisions during the block of trials. Results. As the participants made more decisions, the influence of base rate on choice and confidence increased, which was reflected both in the decision about the direction of motion and in an explicit report about the bias of the block. A bounded evidence accumulation model explained the decisions about motion by incorporating an estimate of the base rate in the accumulation. In turn, a probability distribution over base rates was updated based on the likelihood that the motion was rightward or leftward--what we term counterfactual confidence--under the fictitious supposition that the alternatives are equally likely. The model predicted the dynamics of belief about the direction bias over the block. Conclusions. Our findings establish a role for counterfactual confidence in belief updating, suggesting that the brain maintains probabilistic representations over decision hierarchies and time scales: direction over one trial and bias over many trials. Further, these probabilities are accessible for explicit report.

C. Individual & Lifespan Differences

3-C-11 Applying marketing research methods to decision-making in the criminal justice system

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Examples of wrongful convictions in the U.S. have sparked widespread efforts to understand and improve decision-making in the criminal justice system. Here, we show that an experimental approach adopted from marketing research can replicate effects on judgments of guilt or innocence that have been shown to be important risk factors for error in real criminal prosecutions. Our approach combines a high-throughput behavioral task with hierarchical Bayesian analysis, similar to conjoint analysis used in marketing, to quantify the effects of crime type, evidence, and other variables on confidence in a defendant's guilt. In our first study, for example, we described 33 crimes, which varied in seriousness from shoplifting to rape and murder. Each crime could be combined with 18 combinations of evidence, including forensic evidence; eyewitness identification; and/or a suspect's prior convictions. For each crime scenario, an individual subject views one randomized combination of evidence; across subjects, all combinations of crime type and evidence are represented. This produces partially-overlapping changes to the scenarios, so that we can estimate the effect size and variance for each subject, each crime, and each type of evidence. Data for subjects who did not see a particular combination of evidence in a particular scenario are treated as missing and estimated using hierarchical Bayesian modeling. Across all subjects, confidence in guilt depended most strongly on the evidence directly linking the accused to the

crime. Independent of the evidence, however, the type of crime affects baseline confidence in guilt, and the magnitude of this bias is positively correlated with the seriousness of the crime. For mock jurors (Amazon Turk), baseline confidence in guilt for the most serious crimes is as large as the effect of an eyewitness identification. Prior convictions had a modest but significant effect. Consistent with these results, studies of real criminal cases show that, where the direct evidence is ambiguous, the likelihood of conviction increases when the crime is very serious and the defendant has a criminal record. The results show that an experimental approach borrowed from marketing can approximate aspects of decision-making known to be important in real criminal cases. This approach complements traditional methods in criminal justice research by allowing rapid, cost-effective studies that can quantify effects of individual variables in a high-dimensional parameter space and by replicating risk factors for errors in criminal justice in a format compatible with brain imaging and other methods for investigating the brain mechanisms involved.

3-C-12 Individual differences in the use of variable budget information in consumer choice

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Objective: Economic theory is often based on the premise that an individual's value or willingness to pay (WTP) for an item is stable, but behavioral studies have shown that context, including "mental accounting" of money into categories, can exert a strong influence on WTP (Tymula et al., 2016; Thaler, 2008). In this study, we examined how budget size influences willingness to buy a variety of consumer items. In particular, we were interested in the individual differences in attentional patterns of information gathering (using eye tracking) that affect the extent to which budget modulates willingness to buy. Methods: Participants (N=71) provided their WTP for 90 items using an incentive-compatible Becker-DeGroot-Marschak (BDM) procedure ahead of the lab study. In the lab, participants saw the same items they had previously rated and chose whether to buy or pass on each item for a given price and budget. The prices were set near their pre-recorded WTP, and the budget ranged from $10-$40. To rule out the possibility of budget effects due to numerical anchoring, we ran a control experiment (N=50) with a similar display of variable numbers instead of budgets, with the instruction that these numbers would not affect the outcome. We used eye tracking to measure individual differences and trial-to-trial variation in the attentional patterns of information gathering. Results: Using a group logistic regression, we found that increasing budget size increases the likelihood of purchasing ($b=.041$, $p<.0001$). The purchasing rate was 25% for a $10 budget up to 49% for a $40 budget, but constant across levels in our control experiment. Despite an overall effect of budget on purchasing, there were large individual differences in the magnitude of that effect. Using individually fit odds ratios for the influence of budget on purchasing, we found that the budget odds ratio correlates with the proportion of time spent looking at the budget area of interest (AOI) ($r=0.43$, $p=.00021$). Furthermore, we found that the relative frequency of budget-price AOI transitions (but not budget-item AOI transitions) correlates with the budget odds ratio ($r=0.43$, $p=.00016$). This result suggests that those who use budget rely on a comparison process of the difference or ratio between price and budget whereas those who don't use budget focus more on the value of the item. Conclusion: We found that increasing the budget size increases the willingness to buy an item at a price near WTP. Moreover, we found that individual differences in attention to the budget, as well as comparisons of budget and price, relate to the strength of the budget effect on purchasing behavior.

3-C-13 Steeper discounting for delayed material purchases than delayed experiential purchases during an intertemporal choice task

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Recent research on preference to the delay of the consumption of experiential purchases over that of the consumption of material purchases has demonstrated that consumers assess more utility from waiting for enjoying experiences than from waiting for acquiring material goods. Extending this point of view, the present study investigates a difference between material and experiential purchases in the discounting rate of a subjective value during intertemporal choices. To this end, subjects first reported material and experiential items that they wanted to purchase. Next, they were forced to make a choice between an immediate and more expensive purchase option and a delayed and less expensive purchase option. The immediate option was fixed to be a single value, whereas the delayed option was presented with one of the 6 levels of time delay along with 6 levels of discounted price. Results showed that subjects exhibited more patience for delayed experiential purchases than for delayed material purchases. Especially, the initial discounting rate of subjective values decreased more dramatically for material purchases than for experiential purchases. These findings suggest that consumer behavior in intertemporal choices may depend on a purchase type. Moreover, different discounting patterns shown for each purchase type can be adopted by emerging purchase platforms (e.g. crowd funding), offering a strategic guideline for a proper period of raising money according to the type of funding.

3-C-14 Neural pattern similarity reveals brand equity

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Memory about a brand (e.g., BMW) is associated with memory about the product category (e.g., car) of the brand. Consequently, when thinking about the product category, that brand is likely to be recalled by the activation of the associative network and to be considered for choice. The strength of mental association between a brand and its product category determines the top-of-mind accessibility of the brand in the product category and constitutes a fundamental aspect of consumer-based brand equity. Despite its importance, the structure of mental association between a brand and a product category is largely invisible to traditional behavioral measurements. We posit that the strength of mental association between a brand and its product category can be operationally defined as the similarity of the neural representation between the brand and the product category. We hypothesize that neural representational similarity between a brand and a product category will predict the ease with which the brand can be recalled when consumers think about that product category and the market share of the brand in that product category. To test our hypotheses, in an fMRI study, we first recorded the process of brand recall when consumers were cued by the product category "car", and then recorded their' neural activity in response to car brands and the product category "car". For data analysis, we first calculated the neural pattern similarity between the product category "car" and each car brand, and then linked neural pattern similarity to brand recall and market share. Results showed that the order of car brand recall was predicted by the similarity of neural representations between car brands and the product category "car" in ventral medial prefrontal cortex, posterior cingulate cortex, and lateral temporal cortex--a neural network linking semantics to personal value/identity. Furthermore, we found that neural pattern similarity was predictive of the market share of car brands. Our study suggests that neural pattern similarity between brand and product category has potential to be a new indicator of brand equity. Our measurement implicates a novel application of neuroscientific technique to business.

3-C-15 Neural affective predictors of internet video engagement

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Affective circuits, including the nucleus accumbens (NAcc), anterior insula (AIns), and medial prefrontal

cortex (MPFC) have been robustly implicated in decisions involving money both at the individual level, and at the market level. Less is known, however, about the role that these circuits play in decisions about time. We conducted a fMRI study to test whether neural and affective responses predicted (1) how much time subjects spend watching videos, and (2) how frequently these videos are viewed on the Internet. Subjects watched 32 YouTube videos with the option of skipping each video at any time, while undergoing fMRI. Within sample results were consistent with previous research in the financial decision-making domain, with self-reports of positive arousal positively associated with view percentages ($\beta = 0.091$, $p < 2 \times 10\text{-}16$), and negative arousal negatively associated with view percent ($\beta = -0.031$, $p < 0.001$). These patterns were paralleled in the fMRI results, increased activity in NAcc ($\beta = 0.106$, $p < 0.001$) and MPFC ($\beta = 0.040$, $p = 0.01$) at the onset of the videos associated with increased view percentage, and greater activity in AIns during onset associated with reduced view percentage ($\beta = -0.190$, $p < 0.001$). Next, we tested whether view frequency (views per day) at the market level could be forecasted using self-report and neural measurements from our sample. For the self-report data, neither self-report nor behavioral data were significantly related to view frequency. In contrast, NAcc activity at video onset positively forecasted ($\beta = 6.33$, $p < 0.001$) market-level view frequency, while AIns activity at onset negatively forecasted view frequency ($\beta = -4.64$, $p < 0.05$). Furthermore, NAcc activity continued to forecast view frequency after controlling for the self-report and behavioral measurements ($\beta = 5.39$, $p < 0.01$). These results converge with prior research indicating that NAcc, AIns, and MPFC signals are predictive of subsequent choice in monetary domains over and above self-report. Furthermore, only a subset of these fMRI measurements forecasted market-level demand. In particular, while NAcc and MPFC signal predicted subjects own engagement, it was NAcc and AIns signal that generalized to predict Internet viewership. Thus, low-level affective circuits carry signal about components of a decision that may be more generalizable across people than self-report, behavior, and fMRI measurements obtained from more integrative brain circuits. These data provide evidence for hidden information in neural affective computations that may be inaccessible through self-report (Knutson & Genevsky, 2018).

D. Finance

3-D-16 The temporal dynamics of guilt-induced motivational orientations: A mouse-tracking study

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Objective: Social emotions, such as guilt, serve complex social function and can induce various motivational orientations influencing behavior. Previous research showed that following a moral transgression, guilt feeling motivates transgressors to compensate for their wrongdoing, but also motivates the avoidance of facial contact with the victims. The current study aims to examine the temporal dynamics underlying this approach-avoidance type of decision following guilt feeling. Methods: 74 college students took part in an interpersonal game in groups. Each group of participants (4, 6 or 8 people according to the attendance) sat in a testing room in front of interconnected computers, shielded from sight and supported by video cameras allowing for online face-to-face contact. Participants were allocated as A and B players, each player were randomly paired to perform a perception decision task together (bar orientation judgment). Any failure at the task caused player B to bear a monetary loss. Three levels of guilt were induced in player A, according to the level of responsibility leading to player B's loss: A-incorrect, both-incorrect and B-correct. After each failure at the perception task, player A was required to make a binary choice by using the computer mouse. Each option involved two variables: a certain amount of money to compensate for player B (with no cost for player A), and a certain probability of face-to-face video contact with the victim. Mouse-tracking method was used to track the dynamic processes of participants' choice preference. Results: We ran a multi-level regression of

participants' choices on the final decision points. Results showed that they selected the higher compensation option under all levels of guilt conditions, and avoided video contact with the victims under high and medium levels of guilt conditions, but no significant preference was found for low guilt condition. Regression of mouse-trajectory angle at each time point showed that, under high guilt condition, regression coefficients for video contact started to be significant earlier than for compensation, indicating that avoidance orientation emerged earlier than approach orientation. Moreover, the starting time of compensation orientation delayed while guilt level increased, indicating more intense motivational conflict under stronger feeling of guilt. Conclusions: The findings extend previous studies on the mechanisms driving guilt-induced behaviors, highlighting the underlying motivational conflict and revealing the temporal dynamics of the subsequent decision process.

3-D-17 Psychosocial stressors promote opioid use by sharpening the neural representation of subjective value

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Objective: Stress is a major impediment to recovery in mental illness. Treatment-seeking opioid users, for example, experience frequent and intense psychosocial stress that limits their capacity to abstain from drug use, leading to relapse, treatment dropout, and even death. However, how psychosocial stressors bias behavior toward rewarding but overall less adaptive alternatives (e.g., opioid use) and away from an individual's health goals is poorly understood. Here we test the hypothesis that underlying this bias is a stressor- and anxiety-related adaptation of the brain's subjective valuation (SV) system. Method: We studied 87 chronic opioid users seeking medication-assisted treatment. Patients completed up to 15 sessions (762 in total), during which we probed recent notable life events and state anxiety via interview, and opioid use by self-report and urine drug screens. Text analysis of all interview reports was used to determine the relevant psychosocial domains in which our sample reported life events, and the presence/absence of recent positive/negative events in each domain was coded for each session. A subset of 17 patients (7 scanned 2x) additionally completed a 1-h fMRI scan during which they made decisions about financial rewards that could be delivered with different delays and probabilities. We modeled choice behavior on the tasks to extract estimates of trial-by-trial SV for each patient. To quantify how recent psychosocial stressors and state anxiety affect the neural representation of SV, we examined SV coding in striatum, VMPFC, and amygdala, defined based on meta-analytic data on value and stress. Results & Conclusions: Patients reported having experienced a recent negative event in the psychosocial domains of housing/financial or social/interpersonal in 26% of sessions and a positive event in 19% of sessions. The two event types, positive vs. negative, occurred independently of each other and had differential effects on prospective opioid use, conferring either risk or resilience (adj. R^2=0.43, DF=744; negative events β=0.32, positive events β=-0.30). An increase/decrease in state anxiety mediated these effects (adj. R^2=0.67, DF=734; negative events β=2.52, positive events β=-1.67). Initial fMRI analyses showed that the higher state anxiety following recent negative events correlated with stronger, and more sustained (over the hour long scan), SV coding in the amygdala and the VMPFC, revealing a potential mechanism through which psychosocial stressors can bias behavior toward rewards and consistent with the known effects of stress/arousal on neuromodulator systems.

3-D-18 A surprising source of self-motivation: Prior competence frustration strengthens one's intrinsic motivation in another competence-supportive activity

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According to self-determination theory, competence is among the three basic psychological needs essential for one's well-being and optimal functioning, and the frustration of these needs is theoretically predicted to induce a restorative response. While previous studies have explored the restoration process for autonomy and relatedness, empirical evidence for such a process is still lacking for competence. In order to explore this process and to examine the effect of prior competence frustration on one's motivation to win in a subsequent competence-supportive task, we adopted a between-group experimental design and manipulated one's competence frustration through task difficulty in an electrophysiological study. Participants in both groups were instructed to work on different tasks in two successive sessions respectively. Participants in the experimental group were asked to complete a highly difficult task in the first session and a task of medium difficulty in the second session, while those in the control group were instructed to finish tasks of medium difficulty in both sessions. In the second session, an enlarged feedback-related negativity loss-win difference wave (d-FRN) was observed in the experimental group compared to the control group, indicating that they have an enhanced motivation to win in a subsequent competence-supportive task. Thus, results of the present study provided original neural evidence for the restoration process of the basic psychological need of competence.

3-D-19 Lie to my face: EMG study of facial expressions associated with deception

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Objective: Humans are surprisingly bad at detecting lies; a meta-analysis of 206 studies placed the average rate of successful lie detection at an underwhelming 47%, with just slightly higher performance by experts. The polygraph, a common tool for lie-detection, is also limited; it can be volitionally distorted to mislead investigators. Improving lie detection would have paramount importance in many fields, ranging from everyday social interactions, to business and security. In the current study, we used surface electromyography (EMG) to examine how facial expressions are associated with lying. Our objective was two-fold: (1) To test whether facial EMG signals contain superior information to detect deception; (2) To identify spatial (e.g. electrode locations) and temporal (e.g. latency after stimulus) features that explain individual differences in deception. Method: 24 subjects completed a two-player task while we measured EMG activity from the upper (corrugator supercilii muscle) and lower (zygomaticus major muscle) aspects of their faces. Participants took turns being Sender and Receiver in the task. The Sender's goal was to deceive the Receiver, whereas the Receiver was incentivized to detect such attempts. We applied a machine learning approach to identify muscle activity instances characteristic of deception, and to identify spatial and temporal commonalities that group participants into types. Results: Participants detected deception at 60% (SD=17.2%), slightly above chance ($p = 0.01$). Based on EMG, we decoded deception with an average accuracy of 77% (SD=4.45%) across subjects. Importantly, we found that classification accuracy negatively correlates with successful lying. That is, subjects that were more frequently caught by their human counterparts were also decoded with higher accuracy by the classification algorithm. Finally, we found that participants differ in the locus of their "telltale sign" and can be clustered into two groups: (1) a Smiling group (N=16) who were more accurately decoded based on recordings from electrodes located close to the zygomaticus major; and a Frowning group (N=7), who had more prominent results in electrodes recording from the corrugator supercilii. Conclusion: Our findings validate a novel technique to detect deceit, based on brief and local facial expressions. Our technique is accurate, objective and easy to use. Moreover, our within-subject analysis approach uncovered interesting differences between individuals, possibly explaining the poor performances of existing approaches.

E. Consumer Behavior & Marketing

3-E-20 Influence of fluid intelligence, crystallized intelligence, and grey matter volumes on debt repayment strategies in older adults

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Objective: In real-world population-level studies, advanced age has been associated with less strategic use of credit. It has been hypothesized that both fluid intelligence (the ability to handle novel information) and crystallized intelligence (acquired knowledge, experience, and expertise) contribute to preserved financial management skills in cognitive aging. We examined the influences of both forms of intelligence, and structural brain-behavior associations, in a hypothetical debt repayment task in healthy older adults. Methods: 114 healthy older adult participants (aged 62-93) completed in-person neuropsychological assessments and neuroimaging as well as offsite behavioral measures collected using a web-based survey platform. Debt management strategy was assessed using an incentive-compatible online task (based on Amar, Moty, et al, 2011) in which participants were provided with a budget to repay 4 debt accounts with varying interest rates over 8 rounds. We quantified strategic task performance as the proportion of the budget allocated to the remaining account with the highest interest rate. Crystallized financial intelligence was assessed using a 13-item financial knowledge questionnaire and by surveying participants' experience with different financial products. Fluid intelligence was assessed using standardized measures of memory and executive function. Results: In a behavioral analysis, we constructed a general linear model predicting task performance, using fluid intelligence (memory and executive function), crystallized intelligence (financial knowledge and financial experience), and demographic (age, gender, and education) predictors. Financial knowledge was significantly associated with task performance ($p = 0.048$); financial experience, memory, and executive function were not. In a neuroimaging analysis, we conducted voxel-based morphometry in 90 participants who had undergone MRI within 365 days of task performance, controlling for the effects of age, gender and education. A cluster in right dorsolateral prefrontal cortex was associated with task performance; this association persisted after also controlling for measures of fluid and crystallized intelligence. Conclusion: In healthy older adults, financial knowledge is associated with more strategic debt repayment. This finding suggests that financial literacy education may offset age-related declines in fluid intelligence. In addition, neuroanatomical associations between task performance and dorsolateral prefrontal cortex suggest other neural mechanisms underlying strategic use of credit, independent of financial knowledge and traditional measures of fluid intelligence.

F. Intertemporal Decision-Making & Self-Control

3-F-21 Comprehension as Bayesian decision-making: neural computations of inferring what is meant from what is said in language games

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Communication is a ubiquitous feature of social interactions across multiple species. A cornerstone of effective communication is the ability to recognize the intended message of a speaker for a listener (a.k.a., speaker meaning) even though that message is often not coded in the utterance directly. A number of theoretical and behavioral models of pragmatic reasoning have been proposed, in particular the rational speech act, which connects pragmatic inferences with probabilistic inferences by drawing on formal decision models such as the Bayesian theory. Here, we investigate the cognitive and neural substrates of pragmatic reasoning by exploring brain regions that encode model-derived inference signals used to decipher speaker meaning in a stylized communicative setting. Specifically, we examined

the fMRI data of a language game where a listener needs to infer a target object in a given context based on a message received from an anonymous speaker. Behavioral analyses show that the process of inferring a speaker's intended referent can be characterized as a Bayesian decision process, which integrates the prior information with a mentally simulated likelihood for speaker's actions. Consistent with the behavioral model, imaging data reveal that the latent likelihood signal derived from the model is expressed in the ventromedial prefrontal cortex (vmPFC), even when Bayesian reasoning is unnecessary for discerning speaker meaning (e.g., when speaking meaning is explicitly coded in the utterance). Interestingly, this region also demonstrates model-dependent connectivity with a number of brain regions, including the dorsomedial prefrontal cortex and temporoparietal junction, which are known to be involved in theory-of-mind, and the left inferior frontal gyrus, which has been repeatedly implicated in language processing. The robustness and specificity of the observed behavioral and vmPFC response patterns are further demonstrated in two additional experiments. Together, these results provide a neuromechanistic account of pragmatic reasoning where effective language interpretation arises from a Bayesian decision process, and the vmPFC plays a central role in inferential computations critical for Bayesian reasoning. The data point to a new avenue that bridges the literature of model-based decision neuroscience and that of language and social communication.

3-F-22 Bayesian nonparametric models characterize instantaneous strategies in a competitive game

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Objective: Previous approaches to investigating strategic social interaction in game theory have predominantly used games with clearly-defined turns and limited choices. However, real-world social behaviors involve dynamic, coevolving decisions by interacting agents, which pose challenges for creating tractable models of behavior. Methods: In this study, humans (n=82) played a "penalty shot" game in which they used a joystick to move a virtual puck from one end of a computer screen to the other, attempting to score against either a human goalie or a goalie controlled by a computer algorithm. Participants controlled the instantaneous vertical velocity of the puck, resulting in a game with a continuous action space. Results: We use Gaussian Processes to model the joint distributions of participants' actions and opponent identity (human or computer) as a function of game state. Borrowing from a reinforcement learning framework, we successfully approximate both the policy and the value functions used by each human player in this competitive context. We show that these nonparametric models successfully capture the markedly heterogenous behavior both within trials and across subjects, and, by taking advantage of the fact that our models are differentiable, that it is possible to quantify the instantaneous dynamic coupling between agents. We show that this instantaneous sensitivity to the actions of one's opponent can characterize individual differences in play on a variety of time scales. Finally, we explore how neural activity differs depending on the identity of one's opponent (human or computer) in our paradigm. Conclusions: Using Bayesian nonparametric models, we estimate individualized, continuous policy and value functions in a complex strategic paradigm. This approach offers a natural set of metrics for facilitating analyses at a hierarchy of timescales and suggests new classes of tractable paradigms for assessing human behavior. While the policies and action values we derive offer instantaneous regressors at the tens of milliseconds resolution of electrophysiology, including EEG, MEG, and ECoG, these metrics can also be averaged at the trial and participant level for use with fMRI and PET. Thus, taken together, our results and overall approach offer a new path to the use of more complex and naturalistic paradigms in the study and modeling of social interaction. A related preprint of this work can be found here: https://www.biorxiv.org/content/early/2018/08/05/385195

3-F-23 Persecutory decision-making in psychosis patients playing the Minnesota Trust Game

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Objective: Trust is vital to building and maintaining social relationships; breakdown of trust can have negative impacts on an individual's work and well-being. We used a parametric variant of the Trust Game to address questions of social mistrust and persecutory decision making based on the belief that others are motivated to cause one harm. Methods: The Minnesota Trust Game consists of a two-stage decision with two Players (A and B). Player A decides whether to take a safe lower payout ($10) or to allow B to choose the final outcome. If A allows it, then B decides between an equal payout for both players ($20 each) or an alternate payout that parametrically varied the amount A would receive. The unfair payout provided to A varied from losing $15 to winning $20. Two versions of the unfair payout were tested: one which benefited B ($25) and one which didn't ($15). Theoretically, the version that benefits B could lead to "rational mistrust", in which A recognizes that B would get more money by taking the alternate payout. In contrast, the version that does not benefit B would only be chosen if B was spiteful, and A would only mistrust B if A were concerned about B's desire to cause A harm. Participants completed both stages separately: the first stage in a fMRI scanner, and the second stage outside of the scanner. This within-subject design allowed us to explore how variations in trusting behavior interacted with value circuits within the PFC. 22 patients with psychosis have completed both stages of MTG. Results: Although many participants were worried about being punished by their partner in the first stage, only one participant actually chose to take a smaller payout in the second stage. This finding shows that fears of punishment are unfounded, and that subjects are not simply assuming their partner will act the same way they did. We found a bimodal effect on behavior, in which subjects were either trusting (73%) or fully untrusting (27%) in the spite condition. Those who were untrusting had greater self-reported paranoia as measured by the Multidimensional Personality Questionnaire (MPQ). Less trusting participants showed greater activation in lateral orbitofrontal cortex (lOFC), but only on high risk trials in the spite sensitivity condition. These individual differences suggest this behavior is not a continuum, but rather distinct beliefs. These data find that individuals were overall fair to one another in the second stage, but worried about how partners would act when roles were reversed. Behavioral differences were reflected in lOFC, suggesting interesting potential differences in reward processing when punishment was possible.

G. Game Theory & Strategic Interactions

3-G-24 Differential sensitivity to outcome valence explains age patterns in risk taking and individual variability in memory

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Objective: Laboratory tasks that require learning outcomes and probabilities through experience most reliably evince an adolescent peak in risk taking (Rosenbaum et al., 2017). Presently, we sought to elucidate mechanisms that may underlie developmental change in experiential risk-taking tasks using reinforcement-learning (RL) models. In experiential-choice paradigms, individuals update the value of choosing a given alternative after observing choice outcomes. The magnitude of this update is governed by the learning rate (α), and adults take more risks when α is larger for favorable than unfavorable outcomes (Niv et al., 2012). Presently, we asked whether age-related change in learning-rate asymmetries might account for age patterns in risk taking. We also examined whether valence biases in α modulated memory for pictures presented incidentally with choice outcomes. Method: Participants aged 8-27 (N=62) chose between pairs of risky (50% large gain, 50% no gain) and safe (consistent gain

outcome) "point machines" to learn their associated outcomes and probabilities. Each outcome was displayed with a picture. After the choice task, we tested incidental memory for the pictures. We used an RL model to assess α for favorable (α+) and unfavorable (α-) outcomes, and computed an asymmetry index (AI), representing the relative size of α+ and α- for each participant. Results: Counter to prior literature, adolescents exhibited less risk taking and lower AI than children and adults. Memory accuracy differed by choice context, with greater accuracy for pictures shown after risky than safe choices. Further, those with higher AI showed better memory for pictures presented with better-than-expected outcomes while those with a lower AI preferentially remembered pictures paired with worse-than-expected outcomes. To summarize, risk taking changed with age in a direction opposite to our expectations, and incidental memory varied according to individuals' learning biases. Conclusion: Our work demonstrates age differences in sensitivity to reward statistics of the environment. While unexpected, adolescents' lower risk taking and greater weighting of unfavorable outcomes may result from the 50/50 probability structure of our risky machines. Risks that adolescents take in the real world typically involve less frequent unfavorable outcomes, and perhaps adolescents are risk-averse when risky outcomes are equiprobable. Further, our results demonstrate that episodic memory may be shaped by the choices one makes (e.g., whether one makes a risky or safe choice), and modulated by sensitivity to the favorable or unfavorable properties of the choice outcome.

3-G-25 Reversing typical framing biases predicts self-reported psychopathy: A fuzzy-trace theory approach

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Fuzzy-trace theory (FTT) contrasts risky decision-making based on meaningful gist versus more precise literal thinking, accounting for biases and paradoxes. FTT makes the surprising prediction that these biases and paradoxes emerge from childhood to adulthood. Consistent with FTT's hypothesis that gist-based biases reflect developmentally sophisticated reasoning, unhealthy risk-taking in adolescence has been associated with failure to show irrational biases that characterize healthy adults. In other work, both behavioral risk-taking and brain activation--including criminal risk-taking--correlated with failure to show these biases in adulthood. Here, we extend the research on criminal risk-taking to explore the cognition of adults with psychopathic tendencies. Fifty-six community-dwelling adults (age 26-49) were recruited for an MRI study of risky decision-making. Two hundred sixteen incentive-compatible decisions were made for either money or candy, varying probabilities, outcome magnitudes, and gain-loss framing factorially. Experimental manipulations involving truncation of parts of risky options tested predictions of FTT and prospect theory. Subjects answered a 64-item Self-report Psychopathy scale (SRP-III) and a 59-item Urgency (positive and negative), Premeditation, Perseverance, and Sensation Seeking (UPPS-P) scale measuring impulsivity, among other measures. Experimental manipulations confirmed processing interpretations of typical framing (gist-based) and reverse-framing (verbatim-based) risk preferences. A framing-bias index showed that psychopathy correlated with a behavioral pattern of risk preferences called "reverse framing" (preferring sure losses over a risky option and a risky option over sure gains, the opposite of typical framing biases) that has been linked to risky behavior in adolescents and is rarely observed in nondisordered adults. Regressions predicting psychopathy showed that gender (males were higher in psychopathy) and impulsivity consistently predicted psychopathy scores. Controlling for those factors, the framing-bias index remained a significant predictor of psychopathy. Brain activation in frontal cortical and subcortical reward areas covaried with psychopathy scores. Thus, psychopathy joins a growing list of unhealthy and developmentally inappropriate risk-taking behavioral patterns that are

predicted by reverse framing biases, which FTT identifies as indicative of more-verbatim/less-gist thinking, in conjunction with reward-related impulsivity.

3-G-26 Exposure to violence disrupts adaptive moral inference and trust behavior

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Objective: Exposure to violence (ETV) is a reliable predictor of chronic antisocial behavior across the lifespan. Youth exposed to violence are significantly more likely to display aggression and reduced empathic responses to harm. However, the computational processes that mediate the link between ETV and maladaptive social behaviors remain unknown. Here, we studied adult offenders in a high-security prison to investigate how ETV affects the ability to learn about the morality of other agents and use this information to adaptively modulate decisions to trust others. Methods: Adult offenders (N=119) in a high-security prison predicted the choices of two "agents" who repeatedly decided whether to inflict painful electric shocks on a victim in exchange for various amounts of money. The two agents differed substantially in their morality: the "good" agent required more compensation to inflict pain on others than the "bad" agent. Participants periodically rated their impressions of the agent's morality, and how certain they were about their impression. After learning about the agents, we assessed how participants interacted with each agent in a one-shot trust game. We used a hierarchical Bayesian learning model to describe how participants update beliefs about the agents' moral preferences. We tested the effects of ETV on social learning, impressions, and trust behavior using a self-report ETV scale that measured the lifetime frequency of exposure to violent events. Results: Consistent with work in healthy adults, we show that social learning is explained by an asymmetric Bayesian updating mechanism where beliefs about the morality of bad agents are more flexibly updated than beliefs about the morality of good agents. This asymmetry did not covary with ETV suggesting that the computational mechanisms of social learning were largely intact in this sample. However, offenders with increasing ETV showed less differentiation in their impressions of good versus bad agents and smaller discrepancies in the amounts that participants entrusted in good versus bad agents. Importantly, the relationship between ETV and subsequent social behavior was mediated by the extent to which participants differentiated their impressions of good and bad agents. Conclusions: We demonstrate that ETV disrupted the ability to discriminate between morally bad and good agents in subjective impressions of moral character. Consequently, offenders with higher ETV had more difficulty adjusting their behavior towards agents with disparate moral preferences. Our findings reveal a novel cognitive mechanism that may explain the emergence of maladaptive behavior after exposure to violence.

H. Learning & Memory

3-H-27 Time preferences across adulthood

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Objective: Many everyday decisions involve tradeoffs between immediate satisfaction and long-term well-being. A number of behavioral studies have examined adult age differences in decisions to accept a smaller, sooner reward instead of waiting for a larger, later reward, or temporal discounting. While some studies have reported a decrease in temporal discounting with age (e.g. Eppinger et al., 2012), many studies have reported no age effects on discounting (e.g. Rieger & Mata, 2013) or an increase in discounting with age (e.g. Read & Read, 2004). Based on these mixed findings, we predicted a nonsignificant or small negative effect of age on discount rates. Method: We evaluated the reliability of the age effect on temporal discounting with a pre-registered systematic literature review and meta-

analysis of existing studies examining temporal discounting in different age groups (e.g. younger adults vs. older adults) or in adult age-heterogeneous samples. Our initial search identified 2688 independent studies and after screening, we found 32 studies met our inclusion criteria. Within these studies, we found heterogeneity in terms of experimental design (e.g. extreme-group vs. continuous age), methodology (e.g. delay discounting vs. intertemporal choice), and quantification of discounting behavior (e.g. proportion of immediate choices vs. parameters from a computational model). Here in this initial analysis of the data, we focus on studies reporting continuous age effects (N = 20). Of these studies, 14 authors provided raw continuous data for further analysis. For each data set, we estimated both linear and quadratic effects of age and entered these effect sizes into a random-effects model. Because two of the studies reported discounting for gains and losses, we conducted separate meta-analyses for each domain. Results: In the gain domain, we found no reliable relationship between discounting behavior and age (average Fisher r-to-z = 0.060, 95% CI: -0.010 to 0.013) or age2 (r-to-z = 0.253, 95% CI: -0.099 to 0.605). We also found no reliable relationships in the loss domain (age r-to-z = -0.124, 95% CI: -0.290 to 0.041; age2 r-to-z = -0.121, 95% CI: -0.287 to 0.044). Conclusions: Overall, the initial results suggest that age does not reliably explain individual differences in decision preferences. Discounting may remain stable across adulthood. Additional analysis including the data from extreme-group designs and evaluating the effects of the potential mediators (e.g. specific decision task or outcome measurement) may help better explain heterogeneity across the existing literature. 2665 of 2700 characters (not including Acknowledgement)

3-H-28 How beauty affects fairness in social decision making: An fMRI study on face attractiveness and the ultimatum game

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Introduction: Social decision making often requires a balance between emotional and cognitive motivations. Human faces consist of rich social information and face attractiveness significantly affects social interactions. The Ultimatum Game (UG) is a well-established and widely used task to measure individual responses to fairness during social decision making. In this game, a proposer or allocator proposes an offer to split a certain amount of money, and a responder decides whether to reject or accept the offer. Previous studies have consistently showed that human players were more likely to accept unfair offers from high attractive proposers than low attractive proposers. However, the neural mechanisms underlying such beatify premium effect remain unclear. We used functional magnetic resonance imaging (fMRI) to answer this question. Method: Thirty-four health young adults (25 females, mean age = 20.3 years) participated in this study and played the UG as responders during fMRI on a Siemens Trio 3T MR scanner. Imaging data were acquired using a standard echo planar imaging sequence. Two female faces, one high attractive (HA-face) and one low attractive (LA-face), were selected from a Chinese face gallery based on their ratings of face attractiveness from an independent cohort of 103 young adults and used as the proposers in the UG. Statistical parametric mapping software (SPM8) was used to analyze imaging data. Voxel-wise whole brain analysis and region-of-interest (ROI) analyses were conducted. Results: Participants showed significantly lower minimum fairness during the UG decision making with a HA-face proposer compared to that with a LA-face proposer ($p<0.01$). Imaging data showed greater activation in the anterior cingulate cortex/medial prefrontal cortex (ACC/MePFC), right superior frontal gyrus, and left anterior insula for the unfair offer than fair offer for both HA-face and LA-face UG (FWE corrected $p<0.05$). Moreover, insula activation negatively correlated with the unfair offer acceptance rate for the LA-face proposer condition but not for the HA-face proposer condition,

whereas ACC/MePFC activation positively correlated with the unfair offer acceptance rate for the HA-face proposer condition but not for the LA-face proposer condition. Conclusions:Our behavior findings replicate that face attractiveness affects fairness consideration during the UG decision making. Differential correlations between the offer acceptance rates and brain activation levels in the insula and ACC/MePFC for LA-face and HA-face proposers suggest that face attractiveness may alter the balance between emotional and cognitive motivations during social interactions.

3-H-29 Do economic preferences predict obesity severity? Evidence from a randomised controlled trial with medically at-risk patients

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Can excessive weight gain be attributed to the way individuals make economic decisions? We study the relationship between risk tolerance, impatience and self-control and the severity of obesity in a clinically relevant population. We use data from an economic choice experiment conducted on 300 heavy and pre-diabetic adults who participated in a 12-month weight-loss and weight-management randomised controlled trial run by a hospital. Three hundred participants took part in the study to date. Risk and time preference measures were collected through an incentive-compatible task in which participants made choices between monetary rewards with different levels of risk and rewards delivered at different points in time. These measures were collected three times through the 12-month weight-loss and weight-management program: at the initial appointment, at 6 months and at 12 months (the end of the trial). The obesity measures were derived from high-precision clinical examinations (BMI, body fat, waist circumference). Other important background variables on age, socioeconomic status, and personality were collected through a survey. To construct proxies of risk tolerance, impatience and self-control, we used both simple counts of risky and sooner choices, respectively, and joint estimation estimates that allowed us to adjust for the concavity of the utility function. Since the randomised control trial is not yet complete, at this stage we present the associations between the severity of obesity and risk and time preferences at the baseline, i.e. the initial appointment of the 12-month trial. Our findings deviate from previous literature, which finds that more risk tolerant and impatient individuals tend to have higher BMI. Controlling for relevant background variables, we found that the associations between risk tolerance and severity of obesity dependent on the gender of the participant. Additionally, we find that inconsistency in choice is associated with the severity of obesity.

3-H-30 Who would behave riskier in dyad decision and why?

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Introduction: There is ongoing debate about whether people will be more risk-taking when they make decisions for the group under ambiguous situations. As the rapid developed technology enable us to take advices from others much more easily, exploring the mechanism of people's risk-taking behavior change in group-decision is important in the risk management. Method: In current study, we employed computerized Balloon Analogue Risk Task (BART) to quantify participants' risk-taking behavior. In this task, subjects were asked to collect wager of current balloon or inflate it, which may explode and all wager would be lost. In individual decision condition, subject perform the typical BART alone, while in group decision condition, two subjects would sit side by side and make decisions for the same balloon alternately. We also measured the event-related potential (ERP) to look closely into the underlying mechanism of feedback processing. Specifically, in line with previous studies, two components were identified: the feedback-related negativity (FRN) component, which reflect rapid feedback evaluation, and P300 component, which reflects a later, attention-sensitive, more elaborate appraisal of outcome.

Moreover, the Five-Factor personality traits were also collected to reflect subjects' social character. Combing these methods enabled us to examine different feedback processing procedures separately, provide a new comprehensive way to understand people's risk-taking behavior in group. Result: Thirty healthy male students (mean 21.3 years) participated in this study. Behavior results showed that, in group decision condition, subjects with higher Agreeableness pump the Balloon more times until they decide to collect the wager, comparing to individual decision (correlation between Agreeableness score and pump time increase: $r=0.401$, $p<0.029$). When comparing ERP amplitudes between different conditions, FRN were similar ($p=0.519$), while P300 significantly decreased in group decision condition ($p<0.001$). Most interestingly, there is robust correlation between Agreeableness and P300 decrease ($r=0.555$, $p<0.001$). Conclusions: First, subjects with higher Agreeableness increase their risk taking behavior in group decision. Second, unchanged FRN amplitude suggest that the lower level of feedback processing did not change. Third, P300 significantly decreases in group decision and higher Agreeableness showed more P300 decrease, suggest subject with high Agreeableness perceive the negative feedback quiet differently in group decision. They might less influence by the negative feedback.

I. Valuation & Value Systems

3-I-31 Mental model complexity underlies individual differences in adaptive decision-making

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To make effective decisions in uncertain environments, humans build 'mental models' of environmental statistics and adapt these models when environments change. Despite the importance of adaptive behavior in our everyday lives, there are substantial gaps in our understanding of how this model-building process differs between individuals, and the brain networks underlying these differences. Here we provide empirical support that a mental model's 'complexity' is a fundamental characteristic that governs individual differences in adaptive decision-making. Furthermore, we provide evidence that complexity is linked with dynamic fluctuations in pupil diameter, an index of system-wide levels of norepinephrine (NE) related to normative processes involved in mental model updating. We present a novel measure built on the principles of the information bottleneck that computes model complexity as the amount of information encoded from past observations to predict future observations. This measure is obtained directly from subject behavior, without requiring any assumptions about a model's particular form. We used this measure to capture the influence of complexity on subject performance of an adaptive-inference task in which the statistical structure changed at unannounced points throughout the task. Consistent with the well-known tradeoff between bias and variance in statistics and machine learning, subjects with more complex models were best able to adapt appropriately to real changes in the task environment, but were also more prone to overfit noisy, spurious events. Conversely, subjects with less complex models were less adaptive to task changes, but more robust to noise. In a second experiment, we found that mental model complexity was related to low frequency 'tonic' fluctuations in pupil diameter, physiological markers linked to important concepts such as mental effort and fluid intelligence. These results support the notion that mental model complexity is a fundamental component of adaptive decision-making that guides the extent to which new information is integrated into existing beliefs. Moreover, our pupil results suggest that the brain networks involved in modulating tonic pupil diameter underlie individual differences resulting from mental model complexity. Together these results provide critical insights into the information-processing trade-offs made by individual subjects to maintain their beliefs in uncertain environments, and the neurobiological mechanisms underlying these trade-offs.

3-I-32 Functional network reconfiguration during learning in a dynamic environment

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Objective: In dynamic environments, in which the underlying states can change, learning rates should be adjusted adaptively. Learning should be faster (i.e., beliefs should be revised more) when outcomes are surprising (i.e., a likely change in state) or during periods of high uncertainty (specifically, uncertainty about the current state that is reducible). Previous work has shown how surprise and uncertainty lead to univariate changes in neural activity in DMFC, DLFC, anterior insula and posterior parietal cortex. However, adjusting learning rates likely involves not just changes in the activation of individual regions but also the communication between regions. This study aimed to understand how large-scale functional networks are reconfigured in response to the need to adjust learning rates in dynamic environments and whether such reconfigurations reflect individual differences in adaptive adjustments. Methods: We re-analyzed data from a previous published study, in which thirty-two participants performed a predictive inference task in an MRI scanner. They were required to infer an environment's state based on noisy evidence. Occasionally, the state changed without notification and participants had to infer the new state based on current observations. To characterize dynamic functional networks during learning, non-negative matrix factorization was applied to derive subgraphs (i.e., a spatial pattern of functional connectivity between brain regions) and their time-dependent expression (i.e., the magnitude of these subgraphs over time). Results: We identified a single subgraph linked to behavior across time and individuals. This subgraph involved stronger connectivity between the fronto-parietal and cingulo-opercular networks and multiple other large-scale networks and stronger connectivity within these same networks. The time-dependent expression of this subgraph increased with both surprise and uncertainty. Additionally, the average expression of this subgraph was higher in individuals who performed more adaptively, adjusting their learning rates according to levels of surprise and uncertainty. Conclusions: We identify for the first time a reconfiguration of large-scale functional networks that is associated with adaptive adjustments in learning rates in a dynamic environment. A functional network configuration involving greater between-network connectivity to the fronto-parietal and cingulo-opercular networks is strongly expressed during periods of fast learning (i.e., when surprise and uncertainty are high) and also strongly expressed in individuals who make more adaptive adjustments.

3-I-33 How response time analysis aides model selection in memory-based decisions

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Every-day decisions often involve the retrieval of relevant information from episodic memory. To investigate the underlying cognitive and neural mechanisms, we performed experiments in which participants completed a remember-and-decide task (Gluth et al., 2015, Neuron; Mechera-Ostrovsky & Gluth, 2018, Scientific Reports). This task required participants to associate a snack with a given location during an encoding phase. Later, they had to retrieve snack identities from memory to make informed preferential choices between two snacks. In some critical trials, retrieval was only successful for one snack ("remembered") but not for the other ("forgotten") option. In these trials, we observed a bias in choice behavior (memory bias on choice) in the sense that even relatively unattractive remembered snacks were preferred over forgotten ones. In this study, we compare two process models which can account for the memory bias. A single-process diffusion model (SPDM), proposed in Gluth et al. (2015), assumes that people decide based on comparing the value of the remembered option with a below-average reference value representing the forgotten option. As an alternative, the dual-process diffusion model (DPDM), similar to Alós-Ferrer (2018, JBDM), assumes that people arbitrate between a "heuristic"

process (that chooses the remembered option with some probability > .5) and a "utility" process (that compares the remembered option with the average value of a set). We show that these models predictions can be similar for choice data but differ with regard to response times (RT): The DPDM predicts slowest RT when the value of the remembered snack is at average, whereas the SPDM predicts slowest RT for values below average. We analyzed choice and RT data from N = 90 participants who performed the remember-and-decide task. The RT analysis gave strong support for the SPDM account: RT were slowest when the value of the remembered option was below average ($t(89) = 4.24$, $p < .001$, $d = .45$). This effect was correlated with the memory bias on choice ($r(88) = .35$, $p < .001$), suggesting a common underlying mechanism. Moreover, a random-effects regression analysis revealed that assuming a shift of the RT peak from average to below-average values led to a significant improvement of the the regression models fit ($\chi2 = 224.11$, $p < .001$). In sum, we compared two models with similar predictions on choices by deriving qualitative predictions on RT data. Our analysis provides evidence that the SPDM explains the memory bias better than the DPDM. These findings underline the advantage of RT analysis to disambiguate between competing cognitive theories.

3-I-34 Trust (not) your heart: The role of affective and cognitive trust, and heart rate variability, on individual performance and learning

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While trust is considered to be a fundamental lubricant of human cooperation, still little is know on how it affects individuals' performance and learning. In this study, we examine the role of affective and cognitive interpersonal trust on individuals' task performance and learning by experience in 60 healthy subjects. Participants were grouped in teams of four and asked to cooperatively perform repetitive sessions of a purposively modified first person strategic video game at the Behavioural Science Laboratory of our Institution. During the sessions, we acquired electrocardiogram (ECG) data of participants by using portable and wearable devices (BioPatch M3). Cognitive and affective trust toward team members were assessed by using psychometric scales and subsequent sample splitting. Participants' performance and learning were computed from the game's scores throughout the sessions. Heart Rate Variability (HRV) linear and non linear features were extracted and analyzed from ECG data to assess the autonomic nervous system (ANS) influence on the heart. The findings indicate that interpersonal trust yield a significant effect on both performance and learning: its affective component is negatively correlated with performance, while cognitive trust is negatively correlated with learning. We also show that HRV dynamics are overall depressed with task repetitions, showing significant associations between ANS sympatho-vagal shifts and performance. Altogether, this study advances the understanding of trust on performance and learning by experience. Methodologically we advance the use of HRV linear and nonlinear analyses, paving the way toward physiologically ANS informed models of individual performance and learning in cooperatively bounded virtual contexts.

3-I-35 How do we build causal models of the future? Evidence from gaze patterns

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OBJECTIVE Many everyday decisions require foreseeing the occurrence of future events and their direct and indirect consequences. In these situations, the way agents build models of the contingency space might affect their ability to respond to potential states of the world. However, it is not clear how agents encode and organize available information to react to future circumstances. In the present study, we investigated the process of generation of contingency models by tracking eye movements of participants who performed a novel causal-inference task. METHOD In the causal-inference task, participants had to

learn deterministic conditional rules regulating the occurrence of interdependent events. After the occurrence of one such event, they had to infer all the conditions that would have followed. We performed within-trial cluster analyses on gaze data to isolate mechanisms specifically related to the processes of encoding and integration of relational information, disentangling them from working memory functions. These gaze patterns were used to identify how agents integrated interdependent pieces of information and thus what type of internal causal model they were building. RESULTS A between-subject cluster analysis on early gaze data revealed the existence of two distinct types of participants in the causal-inference task. A group of (sophisticated) participants systematically searched for both direct and indirect relations between states, building an exhaustive model of the contingency space. Another group of (unsophisticated) participants simply learned binary conditional rules without exploring the existence of second-order relationships between conditions, trying to infer the consequences of an event only after its occurrence. The emergence of these two types of behavior largely explained the ability to predict the occurrence of future events. Analyses of individual cognitive measures revealed that cognitive reflection is associated with the emergence of either sophisticated or unsophisticated representation behavior, while working memory and fluid intelligence modulated performance independently of the type of visual analysis implemented. CONCLUSION Our results reveal the existence of two spontaneous processes of generation of causal models of future events. Since building efficient causal models of contingencies is crucial in several learning and decision-making settings, we believe that our novel gaze-based approach could be used in future research to disclose the sources of heterogeneity in several types of economic behavior.

J. Choice & Choice Mechanisms

3-J-36 Reconciling uncertainty-based theories of human adaptation with prediction-error-based modelling of Goal-Directed Learning

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Motivation: Theories of human ability to detect change and rapidly adapt have focused on tracking uncertainty and surprise. Corresponding neurobiological studies have pointed to a network centered around Anterior Insula (AI) and Anterior Cingulate Cortex (ACC). Modern theories of learning, however, assign a dominant role to prediction errors, and neurobiological studies have associated prediction-error based learning with the dopaminergic system (DA), as well as striatal regions, amygdala (Am) and orbitofrontal cortex (OFC). Risk and surprise only enter to the extent that they modulate the learning rate, but even without such modulation, adaptation will still be effective, albeit slow. As such, risk and surprise play a subservient role, one that could be dispensed with. There is an urgent need for a theory that reconciles the two strands of literature. Methods: We propose a new theory of learning, Reference-Model Based Learning (RMBL), whereby control of the environment is executed against a reference model, and the goal of prediction-error-based adaptation is to minimise negative surprises that emerge when contrasting model outcomes with those of prediction-error-based control of the environment. Here, surprise is defined to be the difference between the actual size of the prediction error and its expectation according to the reference model. Results: We analyse choices in a target location forecasting task where participants were required to adapt to ever-changing conditions. The reference model is a gaussian state-space model where the Kalman filter provides optimal learning/forecasting. The actual target is driven by mixed gaussian/leptokurtic processes, like stock prices in financial markets. Human choices appeared to be consistent with predictions from RMBL, while neither a fully Bayesian nor a traditional TD (Temporal Difference) learning model fit behaviour well. Discussion: First, RMBL provides a concrete, flexible approach to modelling "satisficing" (Herbert Simon); indeed, the RMBL agent does

not optimise. Second, RMBL provides an alternative way to formalise metacognition, different from the hierarchical Bayesian approach. Third, we contrast RMBL with related theories, such as Active Inference (Karl Friston), Actor-Critic Models, and Reference-Model Based Adaptive Control (used in specific engineering applications).

3-J-37 An analysis of decision under risk in rats

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Behavioral economic theories, such as Prospect Theory, describe decision-making under risk, and have characterized systematic decision biases that may reflect fundamental aspects of neural processing. We present a task for studying the neural basis of these biases in rodents by eliciting decisions from description: rats choose between explicitly cued gambles on each trial. Light flashes convey reward probability from each of two nose ports, and auditory click rates convey reward amounts. We used high-throughput training to generate dozens (n=40) of well trained rats, and many tens of thousands of choices per rat. Animals exhibited similar decision biases as humans: rats exhibited diminishing sensitivity to rewards and probability distortion, markedly overweighting low probabilities. Rats also exhibited reference dependence, in which the valence of outcomes (gain or loss) was determined by an internal reference point reflecting recent reward history. Most, but not all, rats exhibited loss aversion (i.e., losses loomed larger than gains). Yet another bias that rats exhibited is referred to as the "hot-hand effect:" rats were more likely to gamble following a risky reward (compared to a guaranteed one). Optogenetic perturbations of orbitofrontal cortex (OFC) during the reward period eliminated this bias. This effect was observed in rats virally expressing halorhodopsin in excitatory cells, as well as transgenic rats expressing channelrhodopsin in a subtype of interneurons (PV-Cre). Laser illumination in sham animals produced no effect on the hot-hand effect. We performed tetrode recordings in OFC, and found that many neurons indeed reflected reward history in their firing rates. Unsupervised methods using populations of simultaneously recorded neurons also found trial-by-trial dynamics that correlated rats' reward history. Therefore, we have observed that rats exhibit similar decision-biases as humans, OFC drives at least one of these biases, the hot-hand effect, in which reward history influences subsequent risky choice, and reward history is strongly represented by neurons in OFC. This allows us to examine the neural representations of economic variables, and use cell-type and brain region-specific manipulations to understand the mechanisms of economic decision-making.

3-J-38 Generalized associations between dopamine receptor availability and risky investment decision making

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Pharmacological manipulations have revealed that enhancing dopamine increases financial risk taking. However, few studies in humans have examined whether baseline individual differences in dopamine are related to performance on risky financial decision making tasks. Few studies in general have directly assessed dopamine function in humans, for example using PET imaging. In the current study, thirty-five healthy adults completed an incentive-compatible risky investment decision making task and a PET scan at rest using [11C]FLB457 to assess dopamine D2-like receptor availability. In the task, participants made choices between a safe asset (bond) and a risky asset (stock) with either an expected value less than the bond ("bad stock") or expected value greater than the bond ("good stock"). After each choice the stock outcome was revealed whether it was chosen or not to facilitate learning independent of choice. Participants then estimated the current probability that the stock was the "good stock" after each trial. We computed five measures of task-related errors including three measures of deviations from Bayesian

maximizing choices (frequency of choosing the lower expected value asset, choice inflexibility, choosing a stock on the first trial) and two measures of error in estimation of the probability of the current stock being the good stock (absolute error and a measure of optimism). From the PET data, we extracted mean non-displaceable binding potential from 4 regions of interest: midbrain, amygdala, anterior cingulate, insula. To avoid excessive individual pairwise analyses of multiple measures of task-related errors and multiple measures of dopamine receptors across regions of interest, we used canonical correlation analysis (CCA). Two canonical dimensions showed moderate to high correlations between the sets of task-related measures and dopamine measures (dimension 1: r = .76; dimension 2: r = .59). Decomposition of the first dimension revealed that midbrain dopamine receptor availability and age were negatively correlated with choice inflexibility and optimism and that amygdala dopamine receptor availability was positively correlated with choice inflexibility and optimism. Follow-up analyses revealed that the effects were more strongly associated with choice inflexibility than optimism. Decomposition of the second canonical dimension revealed a negative correlation between insula dopamine receptor availability and choosing a stock on the first trial. The findings reveal latent associations between baseline neural and behavioral measures suggesting that trait dopamine function may be associated with financial risk taking in healthy adults.

3-J-39 Molecular and molar analyses of T-maze risk-dependent choice in the rat

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Risk-related decision making has been studied by the use of several rat's behavioral models including the probability discounting task, but how long-term values and the different levels of risk involved in decisions with reward uncertainty remains elusive. A T-maze risk-depend choice in the rat has been recently developed in this laboratory, which task is specifically set up to run with the expected value (EV) being equal to 1 between binary choice options (small/certain vs. large/risky rewards). The latter option, when chosen, resulted in provision of 2, 4, or 8 sweeten pellets with a probability (p) of 0.5, 0.25, or 0.125, respectively. Thus, the large/risky reward arm provided three different conditions of reward ratio being manipulated, compared to the choice of small/certain arm, which always provided 1 pellet with p = 1. The tests are then carried out by providing three reward ratios represented as different levels of riskiness (i.e., low, medium, and high). Here, we examined this risk-depend choice behavior at both molecular and molar levels of analysis. A group of twelve rats were used and run with the above-mentioned three reward ratios noted as 1:2, 1:4, and 1:8). Following the habituation to T-maze, the food-deprived rat was firstly forced to enter each of two arms set with a specific amount of reinforcer(s) given by p = 1. There were then five daily sessions of free choice conducted for each of the reward ratios 1:2, 1:4, and 1:8 in sequence. The results of molar analysis showed that choice behavior appeared in risk-prone and risk-averse under low-risk (of 1:2) and high-risk (of 1:8) condition, respectively. These data indicate that the subject would choose more small/certain options as the risk is increased. For the molecular analysis, a trial-by-trial analysis was conducted to reveal which option the subject chose after entering a large/risky arm with and without reinforcer delivery. The win-stay responses were observed in the low-risk condition but not the high-risk one. Conversely, the subject intended to shift entering the large/risky to the small/certain arm (lose-shift) in the high-risk condition. Taken together, these data provide a better profile in explaining risk-dependent choice behavior in the rat which model can be further used in psychopharmacology and behavioral neuroscience to elucidate the neural mechanisms of decision making under risk.

3-J-40 Effects of estradiol on risk aversion and loss aversion in men

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Estradiol (E2) is a steroid hormone with receptors widely expressed in the dopaminergic reward structures, such as the midbrain dopaminergic neurons, ventral striatum, and the amygdala (Caldu & Dreher, 2007), structures that are also associated with risk-taking and loss aversion (Tom et al., 2007; De Martino et al., 2010). E2 is also found to modulate dopaminergic transmission in animals (Becker, 1990; Pasqualini et al., 1995). Despite these links, little is known about how E2 may affect decisions under risk. Correlational studies in women found that E2 levels correlate negative with loss aversion and risk aversion (Lazarro et al., 2016) and positive with individuals' sensitivity to reward (Diekhof & Ratnayake, 2016). However, whether E2 causally affect risk preferences for monetary gambles is still unknown. In this study we examined the causal effects of E2 on risk preferences in men. Eighty-seven men received either a single dose of estradiol or placebo in a double-blind, placebo-controlled study. Participants played a series of 256 choices involving mixed gain-loss gambles with equal probabilities and varying expected values. Participants could either accept or reject to play a gamble, and no feedback was given. In addition, participants also played a series of gain-only and loss-only gambles, to test for differences in general risk attitudes between the groups. We found that the expected value at which participants were indifferent between accepting or rejecting the gamble was lower for the E2 group as compared to the placebo group ($p = .034$), showing enhanced risk-taking for gambles with a positive expected value ($p = .02$). Loss aversion was estimated with a prospect theory-based model using a hierarchical Bayesian approach, and showed that the E2 group were less loss averse and more consistent in their choices than the placebo group. E2 group showed a lower sensitivity to monetary outcome in the gain-only gambles, but not in the loss-only gambles. Concluding, in men, increasing estradiol levels causally increased risk-taking for mixed gain-loss gambles, but not for gambles involving only gains or only losses. Loss aversion estimates captured by Prospect Theory model, revealed that estradiol in men reduces loss aversion, in line with prior correlational studies in women. In addition, estradiol reduces the utility of increasing gains. These findings provide insight into the causal role of estradiol in risky decision-making and suggest that the effects on loss aversion may potentially be driven by modulating dopamine levels.

3-J-41 Effects of nicotine abstinence and presence on striatal function at rest and during risk taking

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Objective: The brain reward fronto-striatal system plays a key role in nicotine dependence. However, it remains unclear how nicotine abstinence and presence affects brain reward system function at rest and during task. We hypothesized that regular nicotine intake may help maintain the fronto-striatal function to be normal in chronic smokers. To test this hypothesis, here we used multimodal functional magnetic resonance imaging (fMRI) and measured both resting cerebral blood flow (CBF) and task-induced brain activation changes in the fronto-striatal circuits in smokers after overnight nicotine abstinence (ABS) as compared to these smokers during smoking as usual (SMK) condition and compared to non-smoking healthy controls. Methods: Twenty-four chronic smokers (20 males; 22-55 years of age) and 30 demographically-matched non-smoking controls (20 males; 22-55 years of age) participated in the study. All subjects participated in two scanning sessions. For smokers, a SMK scan was conducted when smoking as usual and an ABS scan was conducted following a CO-verified overnight smoking abstinence period. The order of these two scans was counterbalanced across participants. Arterial spin labeling (ASL) perfusion fMRI of resting state and BOLD fMRI of Balloon Analog Risk Task (BART) were acquired for each participant during both scans. Results: Nicotine abstinence significantly reduced resting CBF in the fronto-striatal regions and disrupted task-induced striatal activation as compared to satiated smokers and compared to nonsmoking controls. However, when smoking as usual, smokers and nonsmokers did

not differ on these brain measures. The severity of nicotine dependence in smokers, as measured by the Fagerstrom Test for Nicotine Dependence (FTND) scores, predicted the extents to which abstinence disrupted striatal CBF and task-induced activation. Conclusion: These findings suggest that smokers' frontostriatal reward processing function is disrupted after nicotine abstinence while regular nicotine intake may help smokers to maintain their striatal function to that of nonsmokers.

3-J-42 Influence of volatility on learning in complex environments

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The world is both uncertain and variable. When an unpredicted outcome occurs, a decision-maker must be able to distinguish randomness that reflects the stochastic nature of events from randomness that reflects changes in the underlying outcome probabilities. For learning to be successful, the decision-maker must distinguish variability (or expected uncertainty), which should not lead to behavioral adjustments, from volatility (or unexpected uncertainty). Although expected uncertainty can be specific to a stimulus or an action, it is unclear how expected uncertainty of an individual option interacts with environmental volatility, or how rapidly reward contingencies change. Here, we developed a novel concurrent probabilistic reversal learning task to study how volatility and its influence on learning may depend on the relationship between actions in more complex environments. Human subjects learned about the associations between three stimuli (two main stimuli, S1 or S2, and one modulating stimulus, Sm, each with different levels of volatility) and two sets of actions. Stimuli S1 and S2 were associated with two different sets of actions (left /right and up/down) that were rewarded with complementary probabilities and these probabilities reversed every L1 and L2 trials (L1 << L2), respectively. Reward probabilities for actions associated with stimulus Sm reversed every Lm trials. Using this task, we examined how the influence of Sm volatility depends on whether its actions match those of either S1 or S2, or by similarity of Lm to L1 or L2. To measure the effect of modulating stimulus on learning of the main stimuli, we used performance, overall response to reward feedback, and fit of choice behavior. First, we found that for the volatile stimulus (S1), learning was slower when its actions matched those of the stable Sm (Lm ~ L2). In contrast, learning of the stable stimulus (S2) was enhanced when its actions matched those of the stable Sm. Overall performance was attenuated for stimuli with actions matching those of Sm, perhaps due to interference, and this attenuation was reflected in the estimated stochasticity in choice. Second, we found that modulation of learning was mainly due to differential response to negative reward feedback between different conditions. Specifically, the learning rate on unrewarded trials and LoseSwitch strategy increased (decreased) for the stable (respectively, volatile) stimulus when its action matched those of Sm. Taken together, our results demonstrate that stimulus-action learning is strongly influenced by the volatility of other stimuli that share the same actions.

K. Social Rewards & Social Preferences

3-K-43 Characterization of the selfish personality

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Objective: Social preferences vary, with some individuals demonstrating excessive selfishness in sharing resources. The independent roles of affective and cognitive empathy and psychopathic and narcissistic traits in predicting selfishness have not been well characterized. Methods: In a preregistered replication and extension of a first round of data collection, the current study examined the roles of empathic traits in generosity and inequity aversion in an incentive-compatible modified dictator game (DG), in which participants decided unilaterally how to split a sum of tokens with another participant across varying

exchange rates (Saez et al., 2015). Adult participants across the United States recruited via mTurk (n = 317) completed the modified DG and self-report measures of personality traits. All measures from Round 1 were repeated. Additionally, a secondary measure of empathy, separate measures of entitlement and exploitativeness, and measures of alexithymia and aggression were examined here in Round 2. Results: Partially replicating Round 1, affective empathy independently positively predicted DG generosity and negatively predicted DG inequity, though whether cognitive empathy independently had the same associations depended on the measure of empathy used (Interpersonal Reactivity Index vs. Affective and Cognitive Measure of Empathy). Also replicating Round 1, psychopathic coldheartedness and narcissistic entitlement and exploitativeness both independently predicted decreased generosity and increased inequity in the DG. Consistent with predictions, proactive aggression predicted DG inequity. Contrary to predictions, alexithymia was unassociated with DG generosity and inequity. Aversion to advantageous inequity was associated with affective empathy, one of two measures of cognitive empathy, narcissistic entitlement and exploitativeness, psychopathic coldheartedness, and an aspect of alexithymia. Factor analysis of self-reported personality traits from Round 1 produced behavioral and empathic factors that both predicted DG selfishness. This factor structure was replicated in Round 2, with and without the measures unique to Round 2. Conclusion: This study at the intersection of social and personality psychology and behavioral economics better characterizes the selfish personality in a large national sample. Across two studies, results highlight that self-reported trait affective empathy may be a better predictor of selfishness than self-reported trait cognitive empathy (though this can depend on the self-report measure used), and both psychopathic and narcissistic traits independently predict excessive selfishness in a non-clinical sample.

3-K-44 Altruistic goal modulates value computation of immoral decisions: An fMRI investigation

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Introduction: Maximizing personal profits often violates one's moral values. Yet, little is known about the neurocomputational process that enables us to resolve conflicts between immoral values (e.g., earning money for one-self by benefiting a morally negatively valued organization) and personal financial gain. Moreover, people also encounter trade-off between an altruistic goal (e.g., charity donation) and immoral values. We designed a novel paradigm by using model-based fMRI to address the following questions: 1) Does altruistic goal influence immoral decisions and the presiding value computation? 2) How does altruistic goal affect value integration at the brain level? Methods: Participants (N = 40) were provided with a series of offers involving two parties. Specifically, accepting the offer would always lead to an immoral consequence (i.e., earning money for a pre-selected morally negatively valued organization that endorse gun holding or hunting). In contrast, accepting the offer would either bring monetary profits to themselves (i.e., the self-other dilemma, S-O) in half of the trials or to a preferred charity (i.e., the other-other dilemma, O-O) in the other half. If they rejected the offer, neither beneficiary would benefit. To better estimate people's moral preference, we varied the payoffs orthogonally for each beneficiary involved in an offer across trials. Results: Participants were more likely to accept offers in the S-O (vs. O-O) dilemma after controlling the payoff. Model-based analyses further demonstrated that participants weighted more negatively the payoff of the negatively valued organization in the O-O (vs. S-O) dilemma. The neuroimaging results revealed that value signals were observed in vmPFC and the dACC during the decision-making period in both dilemma contexts. However, the left ventral striatum (VS) displayed stronger sensitivity to the modulation by the gain for participants themselves (vs. charity). Moreover, individual differences in moral preference, characterized by the relative weights for the charity gain and the self-gain (both vs. negatively valued organization),

modulated the context × decision interactive signals in the right DLPFC. Conclusions: These findings pinpoint the neurocomputational mechanisms underlying how people weigh pros and cons in making an immoral decision. Altruistic goal impacts immoral decisions by modifying the computational weights of cost and benefit, and such effect varies from person to person (indicating moral flexibility). However, the altruistic goal does not affect values integration in the valuation network (i.e., vmPFC, dACC).

3-K-45 Hyperaltruism aversion

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Objective: People sometimes choose to act altruistically at a cost to the self. What do observers make of such actions? Typically, people prefer social agents who help others, but in some instances favouring another over the self may violate fairness norms. Here, we pit altruism and fairness preferences against each other, assessing how people evaluate and respond to hyperaltruistic actions. Methods: Participants observed allocation decisions in one-shot dictator games, which they believed were made by other players. In reality they were observing allocation decisions of algorithms designed to be selfish, fair, or hyperaltruistic. Participants evaluated the dictators' decisions, selected whether and by how much to punish them, and then rated how they felt about their own decision to punish or not. Results: Surprisingly, participants evaluated both hyperaltruistic and selfish decisions negatively. Only "fair" decisions, in which dictators divided rewards equally between themselves and the other player, were evaluated positively by the participants. While, hyperaltruistic behaviour was not punished often, when participants did punish hyperaltruistic dictators they felt better about their decision than when they left such behaviour unpunished. This same pattern was observed when participants punished selfish behaviour, but not when they punished "fair" behaviour. Conclusion: Counterintuitively, people respond negatively when observing somebody acting over-generously and experience a positive affective boost after punishing such individuals. These findings suggest that people find unwarranted selflessness aversive. While this may fly in the face of intuition, according to which self-sacrifices would be evaluated positively, our results suggest that people value equal allocation of rewards over altruism.

3-K-46 Positive and negative reciprocity: two sides of the same coin?

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OBJECTIVES: Reciprocity is key to the maintenance of high cooperative levels in society. In general, individuals enforce social norms by reciprocating both negative actions (e.g., punishing unkind behavior) and positive actions (e.g., rewarding generous behavior). Despite the widespread belief that both kind and unkind behavior elicit comparable reciprocity, the relationship between positive and negative reciprocity is yet not well understood. Recent evidence suggests asymmetries in positive and negative reciprocity. For instance, individuals seem to react stronger to unkind than to equivalent kind behavior. However, no studies have yet directly compared positive and negative reciprocity using a single within-subject design that allows for perfect equivalence between both behaviors. METHODS: 18 participants (Mage=21.4 years, SDage=1.5 years, 11 female) took part in the experiment as second movers while undergoing functional MRI. We conducted an experiment where subjects received either negative or positive transfers ranging from -18 to +18 experimental currency units (ECU) from first movers. After learning the transfer they received, they had the opportunity to reciprocate by either giving or taking ECUs from the first mover. Participants' choice could range between 0 to 8 ECUs and every ECU used to punish or reward would respectively decrease or increase first movers' budgets by 3 ECUs. Rewarding and punishing were equally costly to the second movers. Since perceived gains/losses are likely to be influenced by expectations, the relevant reference point may be affected by beliefs. To account for this,

before learning how many ECUs the first mover decided to transfer, participants expressed their beliefs regarding first movers' actions. RESULTS: The behavioral data show symmetric responses to both positive and negative transfers from first movers. Interestingly, however, when expectations are taken into account, we observe asymmetries between positive and negative reciprocity. Individuals react more strongly to perceived negative transfers than to perceived positive transfers. CONCLUSIONS: These findings support the existence of asymmetries in positive and negative reciprocity when taking into account beliefs. Our results suggest that expectations are important in the determination of reciprocal responses and that positive and negative reciprocity are not necessarily opposite sides of the same coin. Results may also indicate the importance of prediction errors to a better understanding of reciprocal behavior. We now turn to imaging data as to explore whether behavioral asymmetries in reciprocity are accompanied by distinct neural mechanisms.

3-K-47 First-order beliefs are encoded in "Theory of Mind" brain regions during altruistic choice

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Brain regions from the "Theory of Mind" network (e.g., TPJ, precuneus) have recently been demonstrated to encode the value of another's payoffs during altruistic decision-making (Hutcherson et al., 2015). However, because these brain areas have been previously implicated in both the representation of other's mental states and moral reasoning, it is not yet clear which of these processes is reflected by their involvement in altruistic choice. To investigate this question, participants completed a dictator game while in an MRI scanner in which they decided whether to accept or reject possible monetary divisions between themselves and a partner. During the task, participants were alternately instructed to think about their partner, think about the ethical implications of their choices, or respond naturally. Following completion of the scanner task, participants rated the same monetary decisions for how their partner would feel about the outcome and how ethical it would be to accept. Focusing on the partner while deciding increased overall activity in the TPJ and precuneus relative to ethics. Moreover, parametric analyses revealed that regions of TPJ and precuneus tracked anticipated partner feelings when making decisions naturally. Meanwhile, the perceived ethicality of a monetary division was encoded in vmPFC. These findings suggest that the "Theory of Mind" network represents first-order beliefs about a partner's subjective outcomes during altruistic choice rather than more abstract ethical rules.

3-K-48 Defeat, cheating, and status-boosting in narcissism and depression

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Objective: Clinical theory portrays individuals with narcissistic personality as depending on external recognition of success and status. Yet, few experimental studies investigated the social decision-making in narcissism, none of them examining the effects of social defeat specifically. We describe a social defeat manipulation and validate it against self-reported narcissistic traits in healthy and depressed individuals. Methods: In a rigged video game tournament, outcomes and opponent's status were manipulated experimentally. Participants played 24 rounds of a modified snake arcade game against virtual opponents, whom they had to defeat to improve their ranking. Each round started with an endowment, and a win resulted in rank increase without a monetary payoff. Participants were told that opponents represented prerecorded previous players. Participants had two opportunities to affect their social status on each round: at trial-start, they could steal points from their opponent, and at trial-end, they could pay a financial cost to buy additional ranks. Narcissism was assessed using the Brief Pathological Narcissism

Inventory (BPNI) and Five-Factor Narcissism Inventory (FFNI) self-reports. The experiment was performed in two samples: 70 healthy undergraduates (mean age: 21.5) and 85 older adults with or without major depression (60 depressed individuals and 25 controls, mean age: 62.6). Analyses employed linear mixed-effects models. Results: Higher narcissistic traits predicted increased stealing and rank-buying. For stealing, this effect was significant with the BPNI in the undergraduates ($\chi^2(1) = 7.77$, $p<.01$) and the FFNI in the older sample ($\chi^2(1) = 5.77$, $p<.05$). For rank-buying, the effect was observed on FFNI in both samples (resp. $\chi^2(1) = 5.80$, $p<.05$ and $\chi^2(1) = 4.54$, $p<.05$). These effects were robust to co-varying for demographics, video game experience and depression. Stealing increased against higher-ranked opponents in both samples (resp. $\chi^2(1) = 8.67$, $p<.01$ and $\chi^2(1) = 21.20$, $p<.001$) but not in depressed elderly who were insensitive to opponents' rank ($\chi^2(1) = 10.87$, $p<.001$). This group had higher BPNI scores than controls in linear models co-varying for demographics ($F(1,76) = 8.74$, $p <.001$). Conclusions: Narcissism involves a heightened sensitivity to social defeat, motivating moral and monetary sacrifices in order to avoid defeat and boost social rank. Narcissistic traits may additionally increase vulnerability to late-life depression, given their co-occurrence in older adults. In turn, depression diminishes responsiveness to others' status in a competitive setting.

3-K-49 Oxytocin modulates amygdala-prefrontal connectivity during social learning for both ingroup and outgroup

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Oxytocin is a neuropeptide that regulates social cognitive processes and affiliative behaviors in the context of intergroup relations. Although previous findings suggest a modulatory role of oxytocin in processing social values for ingroup and outgroup, its influence on the underlying neural circuits is yet to be elucidated. To address this, the present study examines how oxytocin modulates the neural circuits for value computation during social learning in a intergroup context. In a double-blind placebo controlled design, participants were randomly assigned to either oxytocin (OXT) or placebo (PL) group and self-administered intranasal 40 IU/ml oxytocin solution or sterile saline solution. Forty minutes later, following the group membership manipulation procedure (minimal group paradigm: Tajfel, 1970), participants conducted a social learning task during a fMRI scanning session. In the social learning task, participants had to choose one of two fractal images that were associated with 70% and 30% probabilities of earning points. Three pairs of fractals were associated with three within-subject condition in which the participants could earn points for themselves (SELF condition), for an ingroup member (IG condition), or for an outgroup member (OG condition). The learning rate, trial-by-trial chosen values and prediction errors were estimated by using a modified version of the temporal difference model. Behavioral results showed that the PL group learned faster in the SELF and IG conditions than in the OG condition whereas the OXT group did not show such a difference across the reward recipients. fMRI results showed that oxytocin modulates both left amygdala activity and its functional connectivity with the prefrontal cortex during value computation. Specifically, in the PL group, activity in the left amygdala was strongly associated with the chosen value in the SELF condition only; in the OXT group, the value signals in the left amygdala did not differ across conditions. Moreover, the degree of functional coupling between the left amygdala and the subregions of the anterior cingulate cortex (ACC) was modulated by oxytocin. Our findings support the functional segregation of the ACC in relation to the amygdala, as pregenual ACC was associated with learning for the ingroup member, whereas dorsal ACC was involved in learning for the outgroup member - both of which were weakened

by oxytocin. Our findings suggest a possible neural mechanism by which oxytocin may reduce the self-ingroup-outgroup difference during social learning. Oxytocin seems to modulate the neural computation of social value in the amygdala and the amygdala-prefrontal communication.

L. Risk & Uncertainty

3-L-50 Context-sensitive judgment reflects efficient coding of economic attributes

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Descriptive accounts of decision making such as expected utility theory are typically based on a stable set of "psycheconomic" functions specifying the mental representations of economic attributes. However, the psychological reality of such functions has been challenged by evidence that decisions are highly context-sensitive: the mental representation of an attribute value changes depending on the choice set and other attribute values retrieved from memory. One influential theory--decision by sampling (DbS)--proposes that an attribute's subjective value is its rank within a retrieved contextual sample. Here, we provide a normative justification for DbS that is based on the principle of efficient coding. According to this principle, the brain is designed to represent information in ways that economize on our limited neural resources. When neurons are conceived as noiseless communication channels, the efficient representation of information is achieved by a code that minimizes redundancy in neuronal responses. Redundancy minimization requires values to be encoded so that they are uniformly distributed across the response space, which is implemented by the rank transformation of DbS. Context sensitivity may thus arise for the same computational reason in both judgment and perception: our brains must compress the world as best as possible across different environments. However, when inherent cognitive constraints entail that only a finite decision sample can be retrieved, information transmission is impaired. We theoretically specify the problems caused by finite samples and show how efficiency is partly restored by smoothing of the signal, a principle that indicates new ways to generalize DbS. Such generalizations are closely connected to range-frequency theory, which we derive as an optimally kernel-smoothed estimate of rank. Accordingly, this approach can account for sensitivity to the range of attribute values as has been documented in a variety of behavioral settings. Furthermore, our analysis provides a normative rationale consistent with efficient coding for why neurons in orbitofrontal cortex that represent subjective value exhibit quasi-linear tuning curves even when traditional analyses predict nonlinearity. Moreover, we demonstrate that optimal smoothing can explain how context sensitivity is affected by the number of available response categories. We also show how kernel smoothing may psychologically present as reduced discriminability between items in memory, which could help account for phenomena such as compromise effects. Thus, a deeper understanding of why context sensitivity occurs enables us to better predict its properties.

3-L-51 Biased belief updating and suboptimal choice in foraging decisions

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Objective: Foraging theory prescribes an optimal solution to choices that involve comparing the value of an option against an estimate of how prosperous our environment is. But a separate domain of research has revealed that individuals do not always form beliefs about their environment in an unbiased manner. Instead they prefer to integrate information that suggests their environment is better compared to worse than expected. Here we demonstrate how biases in belief updating can manifest themselves in foraging decisions. In doing so we explain a phenomenon with overreaching societal impact - a reluctance to adapt choices when times are tough. Methods: In a series of studies we combined the computational

framework of reinforcement learning with a classic prey selection task from foraging theory in which individuals decided whether to accept or reject sequentially encountered stimuli. Accepting resulted in a reward but also incurred a time penalty. By varying the availability of different types of stimuli we manipulated how rich/poor the environment was and examined whether participants' choices were sensitive to these fluctuations. We modelled choices as the result of a learning process in which individuals maintained an estimate of their environments global reward rate. The specific task structure enabled us to investigate whether trial by trial adjustments to this estimate depended on whether the environment was improving (getting richer) or deteriorating (getting poorer). Results: In rich environments, participants preferentially targeted the most profitable options. In poor environments, they became less selective and accepted less profitable options. These shifts in preferences were observed in response to both local (within block) and global (between block) fluctuations. Crucially however, they were larger when the environment improved compared to when it deteriorated. Choice data was best described by a computational model in which a global reward rate estimate was scaled up or down according to separate learning rates. This enabled the estimate to update sluggishly when the environment deteriorated (causing preferences for options to perseverate) but quickly when it improved (causing preferences to adapt and change). Conclusion: A failure to adjust expectations when an environment becomes worse leads to suboptimal choices. Valuable options are rejected in the false expectation that better options will materialize. Our findings suggest that this tendency arises out of a learning process in which individuals update beliefs about their environment differentially depending on whether outcomes suggest the environment is getting better or worse.

3-L-52 Reduced value contextualization impairs punishment avoidance learning during aging

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Objective. The ability to adapt to new decision environments and to learn from feedback declines with age, resulting in sub-optimal decision-making in elderly. There has been much debate on whether elderly lose their ability to learn from negative feedback. We propose that rather than a specific deficit in punishment vs. reward processing, older adults might be impaired in value normalization. During learning in a specific context, the reward system tunes to adapt to the range of rewards or punishments previously encountered in that context. This value normalization theoretically allows for better discriminating between the values of currently available options. We tested a model of choice that embeds separate modules for value contextualization and learning from counterfactual information. We hypothesized that such sophisticated computations are affected by aging. Methods. A group of 22 elderly (age range 63-86) and a group of 24 young participants (age range 18-53) performed a probabilistic instrumental learning task and a post-learning test. The learning task was designed to manipulate both outcome valence (Reward vs. Punishment) and feedback type (Partial vs. Complete). In Partial feedback contexts, participants were presented with only the outcome of the chosen cue while in Complete feedback contexts, the outcomes of both the chosen and unchosen cues were displayed. Four fixed pairs of cues were used; each corresponding to one of four stable choice context. Results. Receiving a complete feedback rather than a partial feedback equally improved correct choice rate in the young and elderly groups. However, compared to young people, elderly had significantly reduced correct choice rate during learning in the punishment context. Whereas the pattern of post-learning choices was consistent with the value-contextualization in the young group (value inversion in the complete feedback trials), this effect was absent in elderly participants. Computational model estimations confirmed that elderly were able to use the counterfactual information but failed to contextualize values during

learning. The choices of young adults were best explained by a model containing both learning modules. Conclusion. During learning from negative feedback, when the best action - which yields to a neutral outcome - is consistently chosen, values are not updated. Therefore learning cannot be sustained. A solution to this problem consists in considering outcomes relative to the context in which they are delivered. The decline in the ability to use value-contextualization with age can explain the associated selective impairment in learning from negative feedback.

3-L-53 Linking valuation circuitry with maladaptive decision making within the human connectome project

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Objective Various neuroimaging studies have shown that maladaptive decision-making is associated with blunted striatal responses to reward. Yet, recent meta-analytic work has suggested that blunted striatal responses to reward tend to co-occur with heightened orbitofrontal cortex (OFC) responses to reward (Ng, Alloy, & Smith, 2018, bioRxiv), suggesting maladaptive decision making may be linked to aberrant connectivity between the OFC and striatum. Methods To investigate this possibility, we utilized functional data from the Human Connectome Project (HCP), which contains a wide range of data from nearly 1200 participants (Barch et al., 2013, NeuroImage). Our initial analyses focused on 175 participants who engaged in a popular reward-processing task (Delgado et al., 2000, J Neurophysiology). We used measures encompassed in the HCP behavioral dataset as putative markers of maladaptive decision making, including the NIH toolbox Negative Affect Sadness Subscale score, Adult Self-Report-Achenbach system, and history of substance use. Results Consistent with prior studies, we found enhanced activation within VS to receipt of reward (relative to punishment). Understanding activation within the context of networks in the brain, such as the default mode network (DMN), is helpful in probing the neural underpinnings of reward processing. Thus, we next investigated how the receipt of reward and punishment influences the connection between DMN and other neural regions. We found PPI connectivity between the DMN and the anterior cingulate cortex (ACC), a region thought to be involved in reward processing. Furthermore, the connectivity between DMN and ACC that is related to receipt of reward displayed moderate negative correlation ($R = -0.14$, $p = 0.03$) with a behavioral measure of negative affect (specifically, NIH Toolbox Sadness Subscale score) but no relation to receipt of punishment ($p > 0.05$). Conclusions Our results establish links between valuation circuitry and putative markers for maladaptive decision making. Overall, our results further current understanding of how maladaptive motivated behaviors in a healthy population can influence neural connectivity in the reward system.

3-L-54 The role of the mentalizing network in model-based decision-making

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Objectives This study investigates social versus non-social decision-making and model-based versus model-free decision-making. The main objective is to demonstrate that (part of) the mentalizing network, which includes temporoparietal junction, superior temporal sulcus, dorsomedial prefrontal cortex and precuneus, is involved, not only in social but in domain-general model-based decision-making. Introduction Both social and non-social decisions involve a domain-general valuation network. For social decisions in particular, it is thought that social processes feed into valuation mechanisms through the mentalizing network. Indeed, the mentalizing network is involved in various social processes. However, the mentalizing network is not exclusively involved in social processes: it is involved in various nonsocial processes as well. We propose that the mentalizing network is involved in both

social and non-social model-based decision-making. We test the hypothesis that non-social model-based decision-making involves regions of the mentalizing network; and that these regions become more activated the more reliable model-based decision-making is. Methods We use fMRI to identify neural correlates of mentalizing as well as neural correlates of non-social model-based decision-making. We invoke mentalizing activity with a standard false belief task. Model-based decision-making activity is invoked with an adapted two-stage Markov decision-making task in which we also manipulate the reliability of models. Thereafter, we perform region of interest analyses to investigate whether neural activity involved in non-social model-based decision-making can be found in the mentalizing network. Results At the moment of writing this abstract, we are still anticipating the results of our final analyses. It appears that indeed (part of) the mentalizing network is involved in non-social model-based decision-making; and that neural activity in the mentalizing network is positively related to the reliability of (non-social) model-based decision-making. Alternatively, we will report which brain regions outside of the mentalizing network are involved in non-social model-based decision-making and respond to the reliability of models. Conclusions If our hypotheses are confirmed, we will conclude that (part of) the mentalizing network is involved in both social and non-social model-based decision-making; and that the mentalizing network is involved in decision-making when decision-makers have reliable models of the world. Alternatively, we will conclude that regions of the brain that are involved in social and non-social model-based decision-making likely do not overlap.

3-L-55 A quantitative approach to political preference valuation and change

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Unlike value-based decision-making, it is not immediately obvious that political decisions are made using some principled evaluation of alternatives that can be operationalized in the lab. Many scholars consider politics to be a privileged class of decision-making, much like religious beliefs, that defy logical thought processes. Since the mid-20th century, political science has tried to make sense of this behavior, first using normative economic and later decision theoretic models that have been of great use in neuroscience. One school of thought holds political awareness and exposure to new information as the key mediators to political preference change, whereas others emphasize the role of partisanship. We developed a novel psychophysics task that orthogonalizes partisanship and information flow to evaluate the optimal conditions for political preference change--one which renders political decision-making tractable to neuroeconomic-style analysis. Over 500 Amazon Mechanical Turk subjects and 100 traditional lab participants engaged in this task, which consists of making quantitative preference ratings on real proposed laws that have appeared before US Congress. Subjects first reported their preferences based solely on a synopsis of the proposal--subsequently they must reevaluate those preferences after learning about the true percent of Congressmen of each party that voted in favor of the proposed law. Proposals uniformly tiled the space of Democratic and Republican support and were controlled for their intrinsic perceived partisanship, i.e., the true levels of support for each bill were completely uncorrelated with participants' estimates of that support. Behavioral results among both study populations dichotomized the pool: roughly 40% of subjects exhibited robust preference changes (to one or both partisan signals) while the remainder did not. Neither trait-level political awareness nor partisanship alone account for this divide, which casts doubt on the established awareness model for political preference shifts. This result, persistent across repetitions, is key to ongoing functional imaging work that examines political preference representation in the brain. Previous studies report a common currency among neural correlates of economic value and this work will assess whether political preferences lie in this same axis

3-L-56 Behavioral experiments to investigate preference elicitation of scale constants in multi-attribute value theory

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In Multi-attribute Value Theory (MAVT), elicitation of scale constants of attributes is one of the most relevant issues. This kind of decision problem demands an intense cognitive effort for preferences elicitation with decision makers (DMs). Many studies have reported inconsistences in these elicitation procedures. Objective: This study intends to analyze and better understand the cognitive mechanism during the tradeoff elicitation process of scale constants of attributes in MAVT scope, in order to contribute with the reduction of inconsistencies, by obtaining recommendation for the design of decision support system (DSS). Method: Fifty three undergraduate and master students participated in an experiment using a combined set of EEG and eye tracking system, associated with a DSS that supports the tradeoff elicitation procedure. For the elicitation process, the DSS's interface shows numerical and graphical visualization to the subject, regarding to outcomes representing a pair of attributes. Then, the subject compares them and provides tradeoffs between these two attributes, representing their preferences. The subject indicated the preferred outcome and the consistencies with the MAVT were checked. Results: Improvements in the design of the DSS for elicitation can be made based on the combined results of the EEG and eye-tracking experiment. It can be observed different conditions for pursuing recommendations toward the design of the DSS interface for the tradeoff elicitation. These conditions include: fixation region, pupil diameter, power in different channels of EEG, number of attributes, processing time and degree of consistence for choice of outcomes. Among results a few are mentioned. Pupil metrics have not shown variations during the different steps of the elicitation process. During the elicitation process a higher power of the EEG is observed in Alfa band compared with Beta. Steps in which Beta band had lower power indicated possibilities for further analysis with regard to the elicitation process. A higher intensity of activity was observed in the frontal cortex region. Conclusion: the results obtained are to be applied for the improvement of the design of DSS for the tradeoff elicitation procedure and for supporting analysts in their interaction with DMS. This is also being integrated with experiments related to the DSS for FITradeoff method, which can contribute to the enhancement of the consistencies in the elicitation. Still, it has to be investigated for the analysis of outcomes, how the use of graphical information compared with numerical information on tables, can bring a better contribution for the quality of the process.

3-L-57 Explicit value cues alter the decision process

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An important question in decision-making is whether people are attuned to the stakes of their choices. Recent evidence shows that response times (RT) decrease as the values of the options increase. These counter-intuitive results suggest that people might not always be aware of their choices' stakes. In this study, we looked at how the choice process changes when subjects know the decision stakes ahead of time. Participants in our study completed two tasks. First, subjects indicated how much they liked food items on a 0-10 scale. Then, subjects made incentivized choices between pairs of food items. In explicit-value (EV) blocks, subjects were informed that they would be choosing between food items from the top, middle, or bottom third of the rating scale. In mixed-value (MV) blocks, subjects were told that the food items could be from any third. We used the Drift Diffusion Model (DDM) to study differences between EV and MV blocks. The DDM assumes that choices involve a noisy accumulation of evidence

over time. Once the net accumulated evidence passes a threshold, a choice is made. We hypothesized that (relative to the MV blocks) subjects would spend more time and be more accurate in the top-third EV blocks, and spend less time and be less accurate in the bottom-third EV blocks. We expected subjects in the EV blocks to have wider thresholds (in the DDM) in top-third blocks and narrower thresholds in bottom-third blocks. Indeed, we found subjects were fastest when choosing between high-value items in both MV/EV blocks (ps < .001). There was a main effect of condition on RT, indicating that EV choices were faster than MV choices (p < .001). After accounting for this main effect, we observed slower choices in the top-third EV blocks (p = .05), but not faster choices in the bottom-third EV blocks (p = 0.55), compared to the respective MV blocks. While accuracy was greatest in top-third blocks (p = .03), there was no EV/MV effect on accuracy, nor were there any significant condition/third interactions (ps > .05). In DDM fits, drift rates were highest and thresholds were lowest in top-third blocks, reflecting faster and more accurate choices. Additionally, thresholds were higher in the MV blocks than in the EV blocks, showing subjects' need for more evidence before making a choice (reflected in longer RT). Overall, these results indicate that high-stakes choices convey higher-quality evidence, and require less evidence before choosing. This leads to faster choices, without compromising accuracy. Providing explicit information about the stakes leads people to be less cautious, but also affects how they allocate their time between low- and high-stakes choices.

3-L-58 Neural mechanisms of motivational incentive integration and cognitive control

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Motivational incentives play a central role in influencing goal-directed behavior. However, few studies have examined whether and how different categories of incentives are integrated in terms of their motivational influence on cognitive control. We conducted an fMRI study to examine whether the combined diverse motivational incentives (e.g., money, liquids) are in represented as a neural common currency in value-sensitive brain regions, and whether and how this putative motivational signal modulates cognitive control regions in prefrontal cortex (PFC). To test this hypothesis, we developed an innovative task paradigm that quantifies dissociable and integrative effects of liquid valence (e.g., appetitive, neutral, aversive) and monetary rewards on cognitive control. In the study, participants (N=51, 25 females, 18-38 years) performed a cued task-switching paradigm to earn varying monetary reward amount (e.g., low, medium, high) across trials. Critically, post-trial performance feedback - in the form of oral liquid delivery - signaled successful task performance (i.e., accurate and fast responses) and attainment of monetary reward. Thus, the symbolic meaning of the liquid was held constant, and the liquid valence was blocked. A general linear model was performed to extract a time course of beta coefficients for the nine motivation experimental conditions (3 levels of monetary reward, 3 liquid types). Preliminary results revealed distinct temporal profiles of BOLD activation for monetary rewards and liquid incentives in the striatum, anterior cingulate, and frontoparietal network, with highest monetary rewards eliciting earlier BOLD activation compared to medium and lower monetary reward trials. Dorsal striatum activation was associated with liquid salience (i.e., intensity), whereas left medial frontal gyrus activation was association with liquid valence. Taken together, these results provide evidence that human striatum integrates the value of both monetary and liquid incentive types, but this motivational integration may occur via dissociable neural mechanisms depending on the task structure and context. Future directions involve utilizing multivariate approaches (e.g., MVPA) to elucidate motivation-control interactions in PFC, and examining brain-behavior relationships between subjective preferences for different incentives and motivated cognitive task performance.

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