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ABSTRACT BOOK

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Society for NeuroEconomics 2016

Oral Sessions

Sunday August 28, 2016

Session I – Consumer and Organizational Behavior

08:45 – 09:05   Neural Mechanisms Underlying Diversification in Consumer Choice

Linda Couwenberg[1], Maarten Boksem[1], Maciej Szymanowski[1], Alan Sanfey[2], Ale Smidts[1]

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Objective: How do people make multiple selections from an array of available options? In a wide range of decision tasks in which people have to allocate a scarce resource (e.g., money, time, or choices) over a fixed set of options, it has been shown that people tend to diversify. Interestingly, consumers are willing to forgo preferred options and to choose less preferred options in order to obtain choice portfolios with greater variety (Ratner, Kahn & Kahneman, 1999). Past research suggests that the need to diversify could be driven by concerns about satiation (McAlister, 1982), or a desire for novelty or change (Venkatesan, 1973). The current research seeks to provide more insight into these underlying motivations to diversify, using fMRI. Methods: In our task, participants (N = 41) made a series of choices among a set of choice options by evaluating one option at the time. If one decided to accept an option, the particular option appeared in one's 'basket'. We investigate participants' valuation for the different options in the choice set, given the chosen options already in this 'basket'. More specifically, with this task we aim to dissociate whether people diversify because of (1) satiation: their valuation of an option decreases when the same option was already chosen before, or (2) novelty seeking: their valuation of a non-chosen option increases. Results: Using a random effects logit model, we find that choices can be predicted by both the number of times the same option was selected before (ß = -0.54, p < .01), as well as the number of times other options were selected before (ß = 0.31, p < .01). On the neural level, we find that the predicted utilities for options resulting from this model are correlated positively with neural activity in the nucleus accumbens (NAcc) and the orbitofrontal cortex (OFC) while people are evaluating the options. Additionally, the model parameters reflecting the number of times an option was selected before, as well as the number of times other options were selected correlate positively with activity in the precuneus, the ventromedial prefontal cortex (vmPFC) and the angular gyri. Conclusions: Our findings suggest that both satiation as well as novelty seeking drive diversification in consumer choice, and that the NAcc and the OFC track the updating of utility for choice options in the dynamic context of previous decisions when choosing a portfolio of options. In addition, the precuneus, the vmPFC, and the angular gyri, which contribute to evaluating the downstream consequences of decisions and envisioning future events (e.g., Buckner & Carroll, 2007), are associated with both motivations to diversify.

9:10 – 9:30   Responsibility Aversion and Leadership Ability - Behavioral, Cognitive and Neurocomputational Mechanisms

Micah Edelson[1], Rafael Polania[1], Christian Ruff[1], Ernst Fehr[1], Todd Hare[1]

[1]*University of Zurich*

Study objective: A key characteristic of individuals in leadership positions is the willingness to assume responsibility for the outcome of others. Here we aim to identify the presently unknown cognitive and neural processes underlying this behavior. Methods: We developed a new paradigm tailored to the examination of responsibility and leadership choices in which individuals face identical decisions under uncertainty that result in real consequences to themselves alone or both themselves and others. We analyzed the choice behavior using a computational model of categorization within a Bayesian

hierarchical framework. Finally, we repeated the behavioral paradigm in a separate group of participants in combination with functional magnetic resonance imaging. Results: First, we established that individuals show a subjective preference for controlling their own outcomes but demonstrated an inherent responsibility aversion to controlling others' outcomes. Crucially, we demonstrated that individuals with lower responsibility aversion displayed significantly better leadership ability as quantified by three independent measures. In fact, responsibility aversion was a better predictor of leadership ability than traditional measures such as risk, ambiguity or control preferences. Furthermore, our computational modeling approach allowed us to explore the potential underlying mechanisms of the decision making process and isolate a latent variable uniquely representing responsibility aversion. The brain imaging data identified a network of regions in which activity correlated with the different subcomponents of the task. Notably, specific connectivity changes within this network predicted both leadership decisions and individual differences in responsibility aversion with a high degree of classification accuracy. Conclusions: These results characterize responsibility aversion as an important social preference and key component of leadership ability that predicts hitherto unexplained individual differences at both the behavioral and neural levels.

9:35 – 9:55   Neural Mechanisms of Everyday Decision-Making Under Scarcity

Inge Huijsmans[1], Leticia Rettore Micheli[2], Wenwen Xie[3], Mirre Stallen[4], Alan Sanfey[1]
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Introduction Scarcity, defined here as the feeling of not having enough of what one needs, can have far-reaching consequences: difficulty in making optimal decisions under conditions of poverty is well documented, and indeed recent work from our lab has demonstrated that a scarcity mind-set leads to impairment on a variety of fundamental cognitive tasks. The current study extends these findings, and explores the question of whether resource scarcity in one domain can impact choice behavior, and underlying neural mechanisms, in an unrelated domain. Methods While undergoing fMRI, participants (N = 47) were placed in mindsets of scarcity and of abundance, in a counterbalanced order. During each phase, participants performed an ostensibly unrelated shopping task, indicating how much they were willing to bid to obtain various supermarket products. These auctions were resolved by a Becker-DeGroot-Maarschak compatible auction mechanism. One trial was selected for actual payout. One to two weeks later, participants returned to the lab and rated each product separately on several scales to assess individual preferences of the products. Results Behavioral analyses showed that in the first run, participants bid significantly more for more liked products when in a scarcity compared to an abundance mindset (r = .43 and r = .15 respectively, X2 = 16.14, p<.001). Participants did not adjust their behavior after switching conditions in the second run, likely deciding on a particular behavioral strategy. Neuroimaging analyses demonstrated that viewing products was associated with greater activation in the ventromedial prefrontal cortex when in a scarcity mindset, compared to an abundance mindset (whole brain p<.001 uncorrected, cluster level FWE p<.001), indicating that the scarcity mindset induced stronger sensitivity to potential acquisition of products, in an area known for involvement in value based decision making. Additionally, participants showed diminished dorsolateral prefrontal cortex activation when bidding under scarcity compared to abundance (whole brain p<.001 uncorrected, cluster level FWE p=.002). This suggests that it may be more difficult for those in a scarcity mindset to regulate their initial behavioral instincts, which may provide a mechanism for the finding that participants in a scarcity mindset place higher bids for preferred products. Conclusion These results are notable because they demonstrate a significant impact of scarcity in an unrelated domain, and provide suggestions as to the

underlying brain mechanisms. This clearly outlines the potential wide-reaching effects of the feeling of not having enough on human decision-making.

10:00 – 10:20   Divisive Normalization Yields Attraction and Compromise Effects

Ryan Webb[1], Peter Landry[1]

[1]*University of Toronto*

Objective: There is substantial evidence that choice behaviour depends systematically on the choice set in a manner which violates a rational choice model. For instance, adding an alternative to a choice set which is dominated in some attribute dimension can lead to an absolute increase in the choice probability of an existing alternative (e.g. the attraction effect; Huber et al., 1982). A similar result can be demonstrated with the introduction of an alternative which is extremal to one alternative in both attributes (the compromise effect; Simonson, 1989). Here, we propose a neurobiologically-based model of such attribute-level choice phenomena. The model relies on a pairwise comparison of attributes by means of divisive normalization, a neural computation widely observed in cortex across many sensory modalities and many species (Carandini & Heeger, 2012). Divisive normalization scales (or normalizes) neural activity to the aggregate input of a neural circuit, and efficiently codes sensory information. However existing implementations of the divisive normalization computation are incapable of yielding decoy and attraction effects, since these effects require a re-ordering of choice alternatives (Louie, Glimcher, and Webb, 2015). Results: Introducing pairwise attribute normalization into a neuroeconomic choice model simultaneously yields both the attraction and compromise effect from the same neural computation, and yields preferences that are convex in attributes. The statement of these results are presented in two theorems, and characterize the types of choice sets for which one (or the other) result will hold. The model also predicts the nature of the pairwise comparison, providing an explanation for "attribute-based" information acquisition. Evidence for such phenomena can be found in both eye-tracking studies of multi-attribute choice (Noguchi & Stewart, 2014), and has been attributed to function of the ventromedial frontal lobe in lesion studies (Fellows, 2006). Conclusions: These results suggest that choice effects which arise from an ordering of attributes can result from the divisive normalization computation. Since divisive normalization is grounded in the efficient coding of information, this suggests that attribute-level choice "irrationalities" may be optimal given neurobiological constraints. Moreover, the pattern of attribute information acquisition provides a hypothesis for where attribute normalization may be occurring in cortex.

Monday August 29, 2016

Session II – Attention, Learning & Memory

08:45 – 09:05   Seek, and ye shall find patience: Information Search Strategies Both Reveal and Shape Intertemporal Choice

Crystal Reeck[1], Daniel Wall[2], Eric Johnson[3]

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People often discount future rewards, making them less attractive than lower-value rewards delivered sooner. Recent psychological models have highlighted the role of heuristics in intertemporal choice (ITC). Heuristics underlie several contextual influences on ITC (e.g., choices framed as decisions to accelerate compared to delay consumption). Despite growing interest in heuristics in ITC, the extent to which people use different heuristics and the influence of heuristics on patience remain unclear. The present research elucidates the processes underlying these heuristics using information search data, identifying two main types of search strategies and demonstrating that search strategies influence

patience. In Study 1, participants (N=193) completed an ITC task in which decisions were framed as either choices to delay or accelerate consumption. We used MouseLabWeb, a method similar to eye-tracking, to examine how participants acquired information during deliberation. Importantly, there were substantial differences in process across individuals, and analyses revealed two dominant strategies across individuals. Some people integrate both information about the timing and monetary value of an option, searching in an alternative-based manner. Other people instead search comparatively, evaluating how options differ on a key attribute (e.g., monetary amounts) and searching in an attribute-based manner. Importantly, differences in search also significantly predicted differences in choice. Comparative searchers were both more patient than Integrative searchers and exhibited a larger effect of acceleration framing. In Study 2, we re-analyzed data from a previous experiment in which participants (N=20) completed an ITC task while undergoing functional neuroimaging and eye-tracking. Comparative searchers exhibited greater activation for delay compared to acceleration framing in lateral prefrontal cortex, ventromedial prefrontal cortex, and ventral striatum. Studies 1 and 2 established a correlational relationship between search strategies and behavioral and neural effects related to ITC. In Study 3, we examined whether search strategies might have a causal influence on choice. Participants (N=207) completed the ITC task in one of two conditions, presenting information in the display to encourage either comparative or integrative search. Consistent with our earlier experiments, those in the Easy Comparative condition exhibited more patience than those in the Easy Integrative condition. These results provide causal evidence that search strategies are related to choice in ITC, informing both decision neuroscience models and choice architecture interventions.

09:10 – 09:30   Less is more: weaker prefrontal cortex leads to better implicit decision making
Dezso Nemeth[1], Karolina Janacsek[2]
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Objective: Human learning and decision making depends on multiple cognitive systems related to dissociable brain structures. These systems interact not only in cooperative but sometimes competitive ways in optimizing performance. Although previous studies showed that manipulations reducing the engagement of frontal lobe-mediated explicit, attentional processes can lead to improved performance in striatum-related procedural learning, the dynamic interplay of the related brain regions has not yet been investigated. Here we present two studies in which we aimed to fill this gap by investigating the functional connectivity and the effect of virtual prefrontal lesion during implicit learning and decision making. Methods: In Study 1, we aimed to investigate the functional connectivity (FC) networks that promote implicit decision making in humans. Young adults performed an implicit learning task while 128 channels EEG was acquired. The task involved probabilistic sequences, which enabled to measure implicit learning of conditional probabilities and decision making. Phase synchronization in seven frequency bands was used to quantify FC between cortical regions during the first, second, and third period of the learning task. In Study 2, we explored the proposed competitive relationship by investigating the effect of 1 Hz transcranial magnetic stimulation (TMS) stimulation over prefrontal cortex on implicit decision making. Results: In Study 1 we found that implicit learning and decision making are negatively correlated with functional connectivity of the anterior brain regions in slow (theta) and fast (beta) oscillations. These negative correlations increased as the learning progressed. In study 2, we showed that reduced prefrontal cortex processes leads to better learning. Conclusions: Our result shed light not only on the competitive nature of brain systems in cognitive processes, but provide evidence that dynamic antagonist brain networks serve a hallmark of implicit decision making.

Keywords: memory systems, implicit decision making, statistical learning, functional connectivity, brain stimulation, prefrontal cortex, striatum

09:35 – 09:55   Reward prediction errors enhance episodic memory

Nina Rouhani[1], Ken Norman[1], Yael Niv[1]
[1]Princeton University

Imagine a lottery player has who been purchasing tickets for one year--which memories push her to keep playing? Is she remembering an average of all her winnings or is she selectively remembering single episodes, such as her highest or perhaps her most surprising win? Bridging research in reinforcement learning, episodic memory and decision making, here we ask how experienced risk shapes how we remember events, and how these memories influence further decision making. A strong link between reward learning and episodic memory is suggested by similar dopaminergic signals projecting to both the striatum and the hippocampus (Shohamy & Adcock, 2010). Specifically, in the striatum, phasic dopaminergic signals track the degree to which actual outcomes are different from what was expected (a "reward prediction error" signal). A recent statistical theory of memory formation posited that large prediction errors can not only influence learning, but also lead to the formation of new memory traces (Gershman et al, 2015). In risky environments with larger prediction errors, memory should therefore be fractionated into a larger number of distinct traces. As a result, we predicted better item recall in such high risk environments. Participants (n=200) learned by trial and error which of two types of pictures, indoor or outdoor scenes, leads to higher rewards. Pictures were presented within different contexts ('rooms'), with each room associated with a different degree of reward variance (risk) but matched in mean value, such that the rewards associated with pictures in one room gave rise to higher prediction errors than in the other room. On each trial, participants saw a trial-unique image, entered their current estimate of how much the type of each scene (indoor or outdoor) is worth on average, and then saw the image along with its actual reward. Participants learned the values for the scenes better in the low-risk than in the high-risk room, although they optimally reduced their learning rate in the high-risk environment. Conversely, a recognition test revealed that memory for high-risk scenes was better than that for low-risk, and that this effect was largely driven by greater absolute (or unsigned) prediction errors at reward outcome. This finding suggests that enhanced memory for extreme outcomes (Ludvig et al, 2014) may actually be modulated by an absolute prediction error signal during learning. In ongoing work we are assessing whether reactivation of memories encoded within different 'risk' contexts differentially biases decisions.

10:00 – 10:20   Motivational processes engaged by levels of reward

Roberto Viviani[1], Lisa Dommes[2], Julia Bosch[2], Julia Stingl[3], Petra Beschoner[2]
[1]University of Innsbruck/Ulm, [2]University of Ulm, [3]BfArM

Objective An extensive literature documents the motivational effect of cues predicting rewards through the action of the dopamine system ('incentive motivation'). In the temporal difference learning model, informative cues are associated with the temporal difference error $\delta(t)$, not with mean levels of reward $r(t)$. We were interested to clarify the nature of the motivation accruing from high $r(t)$ levels, if any, and see with functional neuroimaging if its neural substrates could be identified. The prevalent view is that the motivational effect of high $r(t)$ levels are analogous to those of $\delta(t)$, or that $\delta(t)$ is a comprehensive model of motivational signals. Methods We report on three fMRI studies in which we used a foraging task that when simulated with the same model separates the phases in which a temporal difference error and different levels of reward are present. Participants viewed a cue announcing the level of

reward of a subsequent foraging patch, which could be either 1 or 20 cents at each correct response (change in expectations of reward, δ(t)). In the foraging path, participants were required to press the left or the right button for targets appearing on the left or on the right, respectively (different mean reward rates r(t)). The task differs from previous related paradigms inspired by the model by Niv et al. (2007) in that motor effort was matched at different levels of r(t) preventing motor planning and execution to affect the BOLD signal, reflecting our interest in a motivational signal preceding motor response. To verify that the second phase detects a signal independent of δ(t), we manipulated the predictiveness of the cues: pseudorandom sequence of high and low reward trials (1st study), regular alternation of high and low reward trials (2nd study), regular alternation with participant told of this fact (3rd study). We know from previous studies that these manipulations affect the signal δ(t) associated with the cue. However, it should not affect the signal r(t) associated with the foraging patches. Results While the cue was associated with a signal in the ventral striatum/pallidum that disappeared when predictable, the foraging patches were constantly associated with a signal in the SNpc/VTA and a more posterior area localizable as the peduncolopontine tegmentum. Discussion We will argue that the findings suggest, in contrast to prevalent opinion, that r(t) is associated with a specific form of motivation consisting in a sensitization of the dopamine system to high-reward contexts enhancing the salience of stimuli that are likely to be rewarding. This is an attentional rather than a vigour-of-response effect.

Session III – Social Influences and Social Decisions

14:15 – 14:35   Overcorrection for Social Categorization Information Drives Impact Bias in Affective Forecasting

Tatiana Lau[1], Carey Morewedge[2], Mina Cikara[1]
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Our world requires us to anticipate others' pains and pleasures. These affective forecasts guide how we make everyday and consequential legal and medical decisions for others. When forecasting for themselves, people fail to correct for differences between present and future circumstances; more information results in correction from initial, incorrect judgments. Here, however, we find that when forecasters have more social information, an overreliance on stereotypes leads to overcorrection, making forecasts for others less accurate than in the absence of group membership information. Experiment 1a asks Democrats and Republicans to make affective forecasts for targets in response to a win or a loss outcome in the 2014 U.S. Midterm elections. We compare forecasts for an unidentified voter (e.g., a "person"), in-group member (e.g., a "Republican"), or out-group member (e.g., a "Democrat") to experiencers' responses (members of both major parties polled after the elections). Across win and loss conditions, forecasts for an unidentified voter are the most accurate and not different from experiencers' responses, but forecasts for in-group and out-group members are significantly more extreme than experiencers' responses. Experiment 1b replicates the results at the Harvard-Yale football game. Experiment 2 replicates the results in a puzzle competition and finds that correction for group labels consists of adjusting away from the self. Experiment 3 tests our overcorrection model by placing some forecasters under time pressure. While baseline conditions replicate previous results, forecasts for group members become less extreme when the ability to "correct" is impaired. Experiment 4 shows that stereotypes, not extreme exemplars, drive the effect. We replicate previous results but find that forecasts for a separate target, Buddhists, are significantly less (not more) extreme than forecasts for an unidentified target. Despite changes in forecasts across conditions, forecasters expect their target to be moderately unhappy compared to 100 other peers of the same group, indicating a reliance on stereotypes (i.e., shifting distributions) rather than exemplars.

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Social category information exacerbates impact bias, and considering more categorical information paradoxically leads to less accurate forecasts. This sheds some light on how impact bias may escalate the spiral of conflict; negotiators eschew conflict solutions because they overestimate the pain fellow group members feel in response to a loss. Because many of the decisions we make for others draw on affective forecasts, the insight provided here may help reduce bias in many domains of consequential decision-making.

14:40 – 15:00   Social context influences decision signals in primate ACC
Wei Song Ong[1], Michael Platt[2]
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Coordination and cooperation depend on effective social communication. In humans, brain areas linked to both social behavior and reward are activated by cooperation. The neural processes indexed by these BOLD signals, however, remain unclear. We previously reported neurons in anterior cingulate cortex (ACC) and amygdala signal vicarious reward in monkeys when they choose to reward another. These signals may mediate coordination and cooperation. To test this, we created a new task based on the classic "chicken game." Two monkeys (M1 & M2) face each other across a shared monitor. Two colored annuli framing dot motion arrays and 4 response targets are presented. Color indicates the stimuli belonging to each monkey. On some trials, the larger reward (denoted by visual tokens) lies opposite the controlling monkey behind the opponent's annulus; smaller rewards lie to the left. To obtain the larger reward, M1 goes straight, but if M2 also goes straight the annuli collide and neither monkey gets reward. On other trials, a "cooperation bar" allows both monkeys to obtain larger rewards only if both choose to go left. If only one monkey yields he receives a small reward. On some trials, dot motion coherence is randomized to obscure intention signals. Our 4 trained animals maximized juice intake by attending to the tokens as well as the choices of their opponent. Monkeys' strategies depended on their opponent: the dominant animal in the dyad preferentially aggressed and required more incentive to cooperate, while the subordinate preferentially yielded. Monkeys avoided collisions when intentions were clearly signaled but collided more often when intentions were obscured. Collisions were more frequent when a computer player replayed past trials in the presence of a 'decoy' monkey, compared with playing a computer in the absence of a decoy monkey or playing a live monkey. Together, these findings suggest that monkeys use information about rewards available, intention signals, and social context to make decisions. To determine the mechanisms mediating these decisions, we recorded the activity of 481 neurons from the ACC of two monkeys in these 3 conditions. 42% of the neurons encoded intention information provided by the display in the decoy and computer conditions, but only 28% of the neurons did so with the live opponent. Over half of the neurons in all conditions responded to the delivery of juice reward. In the decoy condition, neuronal responses scaled with the amount of juice received in the selfish condition (the other monkey gets a tiny amount), but not when the same reward was delivered for cooperation ($p<<0.001$). These findings demonstrate that neurons in the ACC respond differentially to the presence and behavior of a (non-)interactive agents.

15:05 – 15:25   Computational and neural mechanisms of altruistic and healthy choices: cognitive regulation in social and non-social choice domains
Anita Tusche[1], Cendri Hutcherson[2]
[1]Caltech, [2]University of Toronto Scarborough
Most decisions that we face involve trade-offs between different choice attributes. The ability to weight these different considerations in a context-sensitive manner is fundamental to goal-directed choice and

self-control, yet remains poorly understood. Our study investigated 1) what neural and computational mechanisms underlie our ability to flexibly weight different choice attributes and 2) are these mechanisms domain-general or domain-specific? Using functional magnetic resonance imagining, we scanned 36 healthy subjects while they completed two choice tasks on separate days. Choices involved either foods that varied in healthiness and tastiness (food task) or monetary proposals that varied in benefits for the self and another (altruism task). In both tasks, participants made choices under "natural" and "attention regulation" conditions (e.g., "focus on the food's healthiness", "focus on your partner's feelings"). On the behavioral level, computational modeling (drift diffusion models) confirmed that attention modified the weights assigned to different attributes of the choice (e.g., increased weight of the food's healthiness; decreased weight of your own monetary outcome), resulting in healthier and more generous choices. Notably, the ability to suppress taste considerations during food choice and to suppress selfish considerations during altruistic choices co-varied, suggesting a common computational mechanism across choice-domains. Multivariate decoding revealed that neural representations of target attributes in both tasks changed in ways that matched the best-fitting behavioral model. Attention-induced changes in social target attribute representations mostly involved social cognition areas (e.g., dorsomedial prefrontal cortex, posterior superior temporal sulcus). In contrast, key areas for enhanced and inhibited representations of non-social target attributes were associated with regulation and attention (e.g., dorsolateral prefrontal cortex [DLPFC], superior frontal sulcus). Importantly, only in the DLPFC did attention-induced changes in social and non-social attributes representations overlap, pointing to this region as the source of the common ability to suppress pre-potent but irrelevant attributes during goal-directed choice. Our results suggest that attentional control may result from the complex interaction between domain-general control and value mechanisms and neural circuits that preferentially represent task-specific information. Moreover, we show that computational modeling and multivariate decoding can reliably map changes in computations that underlie context-sensitive choice and our ability to exert self-control.

Tuesday August 30, 2016

Session IV – Valuation & Value Systems

08:45 – 09:05   Evidence for stochastic discount rates in behavioral and brain imaging data

Christopher Glaze[1], Sangil Lee[1], Joseph Kable[1]
[1]University of Pennsylvania

Objective: A principal goal of neuroeconomics is to explain the stochastic component of choice. For example, given the same repeated choice between an immediate cash reward and a delayed reward of greater value, an "impatient" individual will choose the immediate reward most of the time, but do so inconsistently, sometimes choosing the delayed reward. Random utility models and their neural variants have assumed that this variability comes from random perturbations of either subjective value or downstream motor commands. Here we use behavioral and brain imaging data to show that choice variability in inter-temporal decision making comes from variability in the decision policy itself, with each individual's discount rate fluctuating trial-by-trial. Methods: We collected choice, reaction time and fMRI data from 148 subjects performing an inter-temporal choice task. We fit choice data to hyperbolic discounting (the "standard model") and several alternative models and analyzed imaging data in both cortical regions of interest and two brainstem centers related to learning and reward-based decision making (the locus coeruleus, "LC" and ventral tegmental area, "VTA"). Results: Choice data were best explained by a novel model in which all stochasticity stemmed from trial-to-trial variability in each

individual's underlying discount rate. Choices also showed significant temporal structure, with unexpectedly patient or impatient choices not accounted for by the standard model predicting the same deviations from model fits over the next ~10 trials. These unexpected choices were associated with both slower reaction times and increased activity across cognitive control regions. This increase was independent of reaction times and markedly stronger during unexpectedly patient choices. As with choices, these patterns were also better predicted by the stochastic discount-rate model than the alternatives. Interestingly, increased activity in LC, but not VTA, was also predictive of unexpectedly patient behavior. Finally, individual differences in average discount rate were associated with individual differences in the relative activation levels of both LC and cognitive control regions. Conclusions: Behavioral and neural data both support the idea that each individual implements a stochastic decision policy, with this moment-to-moment variability stemming (in part) from a key brainstem center previously shown to modulate arousal and selectivity of individual sensory neurons to salient stimuli. We propose that "impatient decision-making" is in fact a labile state that can be manipulated by this system, suggesting new ways to experimentally manipulate discount rate.

09:10 – 09:30   Basolateral amygdala supports the value representation and effortful choice of a preferred option

Evan Hart[1], Marisella Garcia[1], Yael Zoken[1], Alicia Izquierdo[1]
[1]UCLA

Organisms are often separated from rewards by work-related costs. Rewards of higher magnitude often have higher costs, while rewards of lower magnitude typically have lower costs. The basolateral amygdala (BLA) is known to be involved in appetitive behavior, but its role in cost-benefit, effort-related choice of qualitatively different rewards (more preferred/less preferred), beyond magnitude differences (larger/smaller), is poorly understood. Objective: We assessed the effects of BLA inactivations on effort-related choice behavior, before or after exposure to choice of a preferred vs. less preferred option. Methods: Rats were first trained to lever press on a progressive ratio (PR) schedule of reinforcement for sucrose pellets. Following ~10 days of PR training, rats were implanted with bilateral cannulae in the BLA. Rats then received further PR testing until stable performance was achieved. Rats were subsequently introduced to the choice procedure: chow was concurrently available in the testing chamber while they could work for sucrose. Rats were infused with either vehicle (aCSF) or baclofen/muscimol (125ng each/hemisphere) prior to test across 4 days. These rats were compared to a separate group of rats that reached stable choice performance before BLA inactivations. Results: BLA inactivations had no effect on a control test of food preference, with both vehicle and inactivation groups exhibiting a strong preference for the sucrose pellets when both options were concurrently freely available. After reaching stable choice performance, BLA inactivations produced a significant decrease in number of lever presses for sucrose pellets, compared to the vehicle group. There was no effect on chow consumption. Critically, when lab chow was not concurrently available, BLA inactivations had no effect on the number of lever presses for sucrose, indicating that primary motivation in the absence of choice remains intact with BLA offline. Additionally, a test under specific satiety for sucrose pellets resulted in a main effect of satiation, yet, as expected, animals with BLA inactivations prior to satiation were less sensitive to devaluation than the vehicle group. Conclusions: The effects of BLA inactivations in our task are not mediated by decreased appetite, an inability to perform, a change in food preference, or decrements in primary motivation. Because animals were more sensitive to effort costs for the preferred option even with previous choice exposure, these data implicate the BLA not in

the acquisition but in the performance of value-cost computations. Taken together, BLA supports the specific value and effortful choice of a preferred option.

09:35 – 09:55   Encoding of value and choice as separable, dynamic neural dimensions in orbitofrontal cortex

Daniel Kimmel[1], Gamaleldin Elsayed[1], John Cunningham[1], William Newsome[2]
[1]Columbia Univeristy, [2]Stanford University

Objective: Orbitofrontal cortex (OFC) has long been implicated in value-based decision-making. However, OFC responses are complex, with individual neurons representing multiple task-relevant signals, such as stimulus value, behavioral choice, and expected reward. It was therefore unclear how mixed responses of a given neuron might contribute to distinct cognitive-behavioral functions theoretically subserved by these various signals. Separately, the tools of dynamical systems theory have provided low-dimensional descriptions of the complex responses of premotor cortices in the context of motor behavior and perceptual decision-making. However, the diverse responses from more abstract association areas, such as OFC, have eluded a compact, satisfying description. Moreover, the application of dynamical systems has largely been descriptive, without rigorous means to evaluate the significance of a given low-dimensional response. Here, we combined dynamical systems theory and statistical hypothesis testing to understand the complex, heterogeneous signals observed in OFC during value-based decision-making. Specifically, we asked how task-relevant signals were encoded at the population level and assessed the stability of this encoding during the trial. Methods: We recorded single neuron responses from macaque OFC while monkeys performed a cost-benefit decision-making task that required animals to evaluate an offer and then maintain an effortful response so as to earn the promised reward. Results: Using a novel dimensionality reduction technique, we identified a low-dimensional subspace in which separable patterns of neural activity (i.e., linear combinations of hundreds of serially recorded neurons) in OFC strongly represented distinct task-relevant variables, e.g., value, choice, and expected reward. We went further and developed novel statistical methods -- applicable to many high-dimensional datasets -- that determined the representations were not only significant in magnitude, they also were stable over discrete temporal epochs that aligned with behaviorally relevant events. Conclusions: The separability and temporal dynamics of the low-dimensional neural representations in OFC suggests they may subserve distinct cognitive-behavioral functions essential for cost-benefit decision-making. More generally, the tight synchronization between behavioral epochs and periods of stable population representations suggests that multimodal association cortices, such as OFC, may organize transiently to support flexible behavior.

10:00 – 10:20   Decoding Preference Uncertainty in the Human Brain

Rafael Polania[1], Marcus Grueschow[1], Christian Ruff[1]
[1]University of Zurich

Objective: It has been known for decades that preference-based choices can vary strongly across time, thus violating axioms of transitivity. However, the biological sources that lead to such variability have remained elusive. We used functional magnetic resonance imaging (fMRI) in combination with computational modelling to investigate two hypotheses derived from theoretical frameworks of value coding in the brain: (1) Can preference uncertainty be extracted from neural population codes in the human cortex? (2) Do agents use these estimates of uncertainty in their preference-based decisions? Methods: We acquired fMRI while participants (n=37) rated a set of food items in terms of their preference to consume them. Participants rated the same items twice, without knowing beforehand

that a second rating phase was going to take place. This allowed us to estimate preference uncertainty as each rating's reliability across both rounds. Immediately after scanning, the same participants were asked to select from pairs of food items the one item they preferred to eat. For our decoding approach, we used a generative model in which each voxel's fMRI activity comprised mixtures of population tuning curves for preferences as well as their correlated noise. This allowed us to reconstruct for each trial a posterior probability distribution over preference values; the mean and standard deviation of this distribution estimates the item's preference rating and preference uncertainty, respectively. Results: We tested our decoding algorithm on several cortical regions routinely found to correlate with subjective preferences. Only in the vmPFC, preference uncertainty decoded from the fitted model predicted the empirically observed uncertainty within and across participants (r=0.51, P<0.001). Crucially, each subject's degree of preference uncertainty decoded from fMRI predicted the degree of choice consistency in the subsequent preference-based decisions (robust regression beta=0.66(±0.15), p<0.001). Thus, observing patterns of brain activity during preference evaluation is enough to predict who will later make correct preference-based decisions. Conclusions: Our results provide first evidence that patterns of neural activity in the human cortex encode probability distributions over subjective reward values, and that this probabilistic information is used to derive preferences and guide decisions. Our findings highlight possible neurobiological origins for the variability of preference-based choices and underline that populations of neurons in the human vmPFC represent preferences in a distributed population-based coding scheme.

Session V – Aging & Computational Psychiatry

14:15 – 14:35   The Shrinking of Anterior Prefrontal Lobe Correlates with Loss of Economic Rationality in Aging

Hui-Kuan Chung[1], Paul Glimcher[1], Agnieszka Tymula[2]
[1]New York University, [2]University of Sydney

Objective: The population of people above 65 years old is growing and work investigating their physical ability, cognitive function and decision making is of increasing importance. However, there is insufficient evidence on the effects of neuroanatomical aging on rationality in decision making. In our study, we used whole brain voxel based morphometry (VBM) analysis to determine where gray matter (GM) volume correlates with the behavioral measure of irrationality in choice. Methods: We recruited 31 (12 male) healthy, right-handed adults over the age of 65. All subjects were functionally normal with mini-mental state examination scores ranging between 26 and 30. To quantify the degree of irrationality, we adopted the behavioral paradigm designed by Harbaugh and colleagues (2001) that estimates the number and severity of violations of the generalized axiom of revealed preference (GARP). In individual trials, subjects chose their preferred bundle of snacks and beverages from a larger set of bundles. Assessing many such choices, we can infer whether the subject obeys transitivity and has monotonic (within reason) preferences. In other words, we can infer if subject behavior is consistent with utility maximization. High-resolution T1-weighted anatomical images were acquired with an MPRAGE pulse sequence using a 3T Siemens Allegra scanner equipped with a custom RF. We then conducted a VBM analysis relating our behavioral measure of irrationality to gray matter volume. Multiple regression analysis was performed. The global GM volume, age, gender, extreme preference, numeracy skill, digit span score, Shipley vocabulary score, and education level were regressed out by including them as covariates of no interest in the design matrix for VBM analysis.Results: Our results indicate that irrationality in choice (the number of choices violating GARP and their severity) increases as GM volumes in anterior prefrontal cortex decreases. GARP violations and their severity were not correlated with the

variables of no interest. In addition, the absence of correlation with mean reaction time suggests that our results cannot be explained by attentional or motivational confounds. Conclusions: We used well-developed behavioral and neuroanatomical analysis to determine which brain structures correlate with the behavioral measure of economic irrationality; our results show that a reduction in anterior prefrontal lobe GM correlates with economic irrationality. These findings point towards a neuroanatomic locus for economic rationality in the aging brain, and highlight the importance of understanding both anatomy and function in the study of aging, cognition, and decision making.

14:40 – 15:00   Behavioural and neural correlates of the gambler's fallacy in Gambling Disorder
Eve Limbrick-Oldfield[1], Rachel Cocks[2], Inge Mick[2], Remy Flechais[2], Michael Aitken[3], Anne Lingford-Hughes[2], Henrietta Bowden-Jones[4], Luke Clark[1]
[1]University of British Columbia, [2]Imperial College London, [3]Kings College London, [4]CNWL NHS
Objective: Gambling is associated with cognitive distortions in sequential decision-making, including the gambler's fallacy (GF; the belief that an outcome is more likely, or 'due', after a run of another outcome). Surprisingly, past research has failed to examine the GF in the context of individuals with Gambling Disorder. We used a simplified roulette task to elicit the GF, and compare choice behaviour and fMRI correlates in a group of patients with Gambling Disorder to a group of healthy controls. Methods: Patients with Gambling disorder (N=18, all male, mean age 31.8 yrs) were recruited through a treatment service (National Problem Gambling Clinic, London, U.K.) and compared with a healthy control group (N=16, all male, mean age 30.31 yrs). The fMRI roulette task entailed a red / black colour prediction, with a variable wager. We used trial-by-trial fixed effects logistic regression to simultaneously model the effect of Colour Run length and Feedback Streak length (Wins or Losses) on Choice behaviour. Imaging analysis used a mass univariate GLM approach to examine how the neural response to Win and Loss outcomes was modulated by Colour Run length, Feedback Streak length, and Next Choice behaviour. Results: Examination of Choice behaviour within the patient group revealed that, after Losses, gamblers were more likely to make a GF Choice as Colour Run length increased (β (SE) = -0.29 (0.05), $p < .001$). This slope was decreased after Win outcomes (β (SE) = 0.20 (0.07), $p < .01$). The behaviour of the control group did not significantly differ from that of the patients. However, within the patient group, increased gambling severity predicted an increased GF slope after Losses (β (SE) = -0.03 (0.01), $p < .05$) and a decreased slope after Wins (β (SE) = 0.04 (0.01), $p < .05$). fMRI analysis comparing the neural responses in patients and controls revealed several group differences. Patients showed an increased response to Losses in the medial PFC and ventral striatum. The ventral striatal activity increased as a function of Loss Streak length in controls, but not in patients. No group differences were observed in the response to Colour Run length. Conclusions: Within a simple binary choice task decision-making is influenced by multiple factors including past outcomes and feedback. Behaviourally, and in line with past work, we see that the GF is strongest following losses. Patients with Gambling Disorder did not differ from controls on the task at a group level, but gambling severity predicted GF decisions following losses. Imaging data also showed reduced sensitivity to Losing Streaks in the patients with Gambling Disorder. These findings may help delineate the mechanisms of loss chasing, a defining feature of Gambling Disorder.

15:05 – 15:25   Mesolimbic dopamine encodes both desire and satisfaction: lessons learned from studies of substance abuse in rats
Paul Phillips[1], Ingo Willuhn[1], Lauren Burgeno[1]
[1]University of Washington

Reward cognition comprises a number of potentially discrete neural constructs. Central to these processes is the notion of desire to obtain a good, and the satisfaction of securing it. While these constructs are commonly lumped together, they have essentially opposite effects on immediate behavior. Desire is an appetitive motivational state that elicits goal-directed behavior, whereas satisfaction is a motivational state that signifies satiety and thereby terminates goal-directed behavior. Pavlovian conditioned stimuli that are associated with rewards often act as 'bridging' stimuli and act as satisfiers, essentially supplanting this action of unconditioned stimulus, and thereby terminating goal-directed behavior. The learned configuration of these stimuli is their presentation as a result of goal-directed behavior. However, when these exact same stimuli are presented in a different context, in the absence of goal-directed behavior (i.e., non contingently) they actually elicit that behavior. In fact appetitive conditioned stimuli are often considered to be some of the most potent elicitors of goal-directed behavior. In this study, we examined mesolimbic dopamine transmission to drug-related Pavlovian cues when they were presented in different configurations, either as a direct result of drug taking behavior, commensurate with their conditioned association, or by non-contingent presentation, unexpected to the animal, a context that typically elicits drug seeking. Dopamine was monitoring with 100-ms resolution in rats that engaged in voluntary, (intravenous) cocaine administration. Under the regimen we used, animals increase their consumption as a function of drug experience and, when drug is not available, they show signs of increased drug craving as assessed by drug-seeking behavior in the absence of drug. Dopamine release to response-contingent Pavlovian stimuli decreased during drug use in animals that increased their drug consumption. Reversing this decrease in dopamine returned drug consumption to baseline levels. However, when the drug cues were presented non-contingently in these same animals, the dopamine signal increased with drug experience and correlated with the increase in the ability of the cue to elicit drug seeking behavior. Therefore, there are diametric changes in dopamine transmission to drug cues over drug experience, depending on the context of the presentation of the cue. These findings demonstrate that dopamine encodes desire and mediates the initiation of goal-directed behavior but, paradoxically, also encodes satisfaction and mediates the termination of goal-directed behavior.

Session VI – Bounded Rationality

15:30 – 15:50   Testing Models of Rational Inattention

Mark Dean[1]

[1]Columbia University

Limits on attention have an important impact on behavior. Incorporating limited attention into economic models has been shown to have a profound effect in a number of important settings, including consumption and savings problems, pricing behavior, and portfolio choice. Because attention is a scarce resource, a fundamental problem for economic agents is how to best allocate their attentional resources. Models of 'rational inattention', which has proved popular in economics, assume that decision makers allocate attention optimally given the costs and benefits in the environments. The aim of this project is to use laboratory experiments to (1) test whether people actively adjust their attention based on the choice environment, (2) understand whether they do so optimally, and (2) if so, learn about their attention costs. Specifically we are interested in whether behavior is commensurate with the commonly used assumption that costs are based on Shannon mutual information (henceforth the Shannon model). In order to answer these questions, we use a novel experimental interface in order to collect 'state dependent stochastic choice data', which records the probability of subjects choosing different alternatives in different possible 'states of the world'. Previous theoretical work has shown this

data to be particularly useful for testing models of rational inattention. Subjects are presented with a screen with 100 balls on it which can be either red or blue. The state of the world is given by the number of red balls. Subjects could, in principal, determine the precise state of the world if they so wished, by counting the number of red balls on the screen. However, to do so would be time consuming, and require cognitive effort. Subjects are then asked to choose between a number of acts, the payoff of which depends on the state of the world. State dependent stochastic choice data reports how often each act is chosen in each state of the world. The resulting pattern of choice data helps us to understand their tradeoff between costly information acquisition and monetary reward. Using this experimental design, we run 4 different treatments designed to answer the three questions above. Our results establish (1) Subjects do actively adjust the information they gather, based on incentives (ruling out alternative models such as random utility and signal detection theory (2) In simple environments, subjects do behave as if they are allocating attention optimally relative to some cost function but (3) These costs vary hugely across subject, but appear to be importantly different from those implied by the Shannon model - for example, costs appear to obey a concept of 'perceptual distance' which is absent from the Shannon model.

15:55 – 16:15   Learning relative values in the striatum induces violations of normative decision making

Gerhard Jocham[1], Markus Ullsperger[1], Tilmann Klein[2]
[1]Otto-von-Guericke-Universität Magdeburg, [2]Max Planck Institute for Cognitive and Brain Sciences
Objective To decide optimally between available options, organisms need to learn the values associated with these options. Reinforcement learning models offer a powerful explanation of how these values are learnt from experience, using prediction errors to update value estimates. However, human choices often violate normative principles. Our previous work lead us to hypothesise that humans may learn option values relative to alternative options with which they are paired during learning. Such relative value learning may lead to seemingly counterintuitive decisions in novel contexts. Methods We used a novel reinforcement learning paradigm in one fMRI and two behavioural studies to show that both behaviour and striatal learning signals are consistent with relative, rather than absolute value learning. Subjects first learnt, by trial and error, to select the more rewarding option from pairs with differing reward probabilities. Outcome information for both options was provided on each trial. After this acquisition stage, subjects were transferred to a novel choice context. Importantly, novel combinations were arranged such that the behaviour of an agent learning relative values was exactly opposite to that of an agent learning absolute values. Results Subjects' choices on the first trial in new contexts were remarkably consistent with those of an agent learning relative values. First, subjects showed no systematic preference for an option that had a higher value than the alternative when both options had previously acquired the same relative value. Second, subjects systematically preferred an option that had previously acquired a high relative value, despite the two currently available options having experienced identical reinforcement histories. Third, subjects even systematically preferred a lower-value option over a high-value option when the former had previously acquired higher relative value. Outcome-related signals in the striatum during learning displayed the key characteristics of a prediction error for updating relative option values. Notably, we found no region in the brain that supported either updating of both options' (absolute) values nor any region separately updating the value of the unchosen option. Conclusions Our data suggest that seemingly counterintuitive decisions may arise as a natural consequence of the learning mechanisms deployed by humans. Specifically, when information about both options is presented, humans appear to learn values relative to the currently available

alternative option. This can profoundly bias later decisions in new contexts. Activity in the striatum reflected a prediction error for updating relative values

16:20 – 16:40   Optimal and heuristic decision-making policies in the human brain

Christoph Korn[1], Dominik Bach[1]

[1]University of Zurich

Objective: Ideally, biological agents should make decisions that minimize imminent and protracted threats. For example, foraging for food averts starvation in the short and/or long term but poses the risk of immediate energy expenditure and of a sudden attack by a predator. Optimal decisions in such cases therefore require an extensive model-based tree search over a vast combination of future states that depend probabilistically on the agents' actions, their energy states, and the foraging environments. To facilitate such computations, humans may resort to myopic model-free heuristics that only rely on the situation at hand and disregard upcoming states. Here, we tested in two independent fMRI studies how humans compute such optimal and heuristic policies. Methods: We designed different Markov decision-making tasks that allowed us to specify different heuristics and to derive a priori optimal policies for minimizing virtual threats (via numerical simulations and dynamic programming). In both studies, participants faced the threat of virtual starvation at different time horizons. In the second study, they additionally risked virtual predation. Results: State-of-the-art Bayesian model comparisons demonstrated that participants performed both a complex model-based tree search over probabilistic prospective outcomes and a simple model-free use of the best available heuristic decision variable(s). The policies were related to macroscopically different brain regions (such as medial prefrontal cortex for the optimal policy, and intraparietal and dorsolateral prefrontal cortices for heuristic policies). Crucially, conflict between the decision policies led to slower reaction times and anterior cingulate cortex engagement. Conclusions: Our findings lend support for parallel computation of optimal policies that explicitly minimize threats over longer time horizons and of heuristic policies that approximate threat minimization with the help of momentary environmental variables. We suggest an arbitration mechanism for the multiplicity of decision controllers involved in addressing the challenges of multistep decision scenarios.

16:45 – 17:05   Multiple timescales of valuation mediate adaptive choice behavior

Kenway Louie[1], Jan Zimmermann[1], Paul Glimcher[1]

[1]New York University

Objective: In dynamic environments, neural systems must encode broad ranges of information despite finite coding capacity. In sensory processing, this problem is widely thought to drive adaptive coding mechanisms like temporal adaptation and spatial normalization. Recent work suggests that similar coding principles operate in reward-processing and decision-related brain areas. For example, neurophysiological and neuroimaging evidence shows that the neural representation of value adapts to the recent temporal reward context. However, the biological mechanism of this temporal adaptation is unclear and its influence on choice behavior is unknown. Methods: We examined behavior in monkeys performing a saccadic decision task for options differing in reward type and magnitude. Individual sessions comprised two blocks differing in overall reward variance. Each block consisted of two types of randomly interleaved trials pairing two types of juice. Measurement trials paired an unvarying reference option (fixed juice type and magnitude) with one of five variable magnitudes of a different juice type; these trials were identical across blocks, and quantified the probability of choice as a function of variable reward magnitude. Adaptor trials paired the reference option with an alternative option whose

magnitude was drawn from one of two block-specific reward distributions (low or high variance). To model choice behavior, we implemented a novel dynamic differential equation model with two cascaded divisive normalization circuits with different timescales of integration. Results: Adaptor reward variance had a significant effect on choice performance: consistent with efficient coding theory, discriminability in measurement trials increased in blocks with low adaptor reward variance. In addition, despite identical task conditions, we found considerable across-session variability in the effect of reward statistics on choice performance. Notably, both the average adaptation effect and across-session variability are reproduced by the dynamic two-stage normalization model. Peak predictive performance occurs at large ratios of relative timescales across model stages, underscoring the importance of short and long timescale integration in the valuation process. Conclusions: These results show for the first time that economic choice behavior adapts to the statistical structure of recent rewards, with increased choice sensitivity under lower reward variance conditions. This adaptive choice behavior is captured by a valuation model with multiple timescales of normalized reward coding, providing a potential biological circuit mechanism for temporal context effects.

Poster Spotlights

1-H-26   **How oxytocin fine-tunes decision making in social dilemmas: cooperate as long as it pays off, but aggress only when you think you can win! An fMRI study.**

Carolyn Declerck[1], Christophe Boone[1], Bruno Lambert[1], Paul Parizel[1]
[1]University of Antwerp

The neuropeptide oxytocin (OT) gained attention in neuroeconomics as experiments with intranasal administration show that it can boost trust, reduce anxiety, and increase the relevance of salient social cues. However, more often, OT has a moderating effect, with pro- or antisocial consequences depending on context. Here we investigate how context matters, and what the effects of OT are when multiple pieces of information have to be integrated at once. Key social decisions require an evaluation of (1) how context incentivizes one behavior over another, and (2) how contextual cues are informative with regard to the outcome of that behavior (i.e., whether the desired behavior is safe or dangerous). Objectives. We set up an experiment to test if OT can improve the accuracy of complex decision-making in strategic interactions by facilitating the integration of incentives and social cues. We also test if this occurs through OT's modulatory effects on the nucleus accumbens and amygdala, two regions of the brain that are involved in generating incentive motivation and in evaluating the valence of social stimuli respectively. Methods. Participants (N = 30) played two economic games under the MRI scanner after they received 24 IU of intranasal OT or placebo (following a double blind, within-subject design). The games vary in the incentives they provide: the assurance game (AG) simulates a win-win environment and incentivizes cooperation, while the chicken game (CG) simulates a win-lose environment and incentivizes aggression. Pictures of angry or neutral faces were displayed on the screen alongside the game matrices in order to suggest a threatening or safe decision environment. Results. In the AG, where cooperation is the most desirable option for both parties, facial cues are not relevant, and OT facilitates cooperation for risk averse individuals. Here OT activates the nucleus accumbens significantly more than in the CG. In the CG, where aggression is the most desirable option but fatal if the partner also aggresses, facial cues are highly relevant. Here OT significantly downregulates the amygdala, while behaviorally, it steers decisions in accordance with the valence of the cue: aggress when cues are neutral; retreat otherwise. Conclusions. Taken together these results are compatible with the theory that OT facilitates heuristic decision making by modulating brain regions in the mesolimbic dopaminergic system. Through its combined effect on the nucleus accumbens and amygdala, cooperative or aggressive decisions are selected in function of the best match between incentives and social cues present in the decision context, thereby improving ecological accuracy.

1-H-28   **Visual search patterns predict the level of sophistication in interactive games**

Luca Polonio[1], Joshua Zonca[1], Giorgio Coricelli[2]
[1]University of Trento, [2]University of Southern California

Objective: Recent eye-tracking studies of game playing suggest the existence of individually heterogeneous-but-stable patterns of visual information acquisition based on subjective levels of strategic sophistication (Polonio et al. 2015). However little is known about the link between basic attentional indices and the level of sophistication in games. Our objective is to directly investigate whether it is possible to predict players' behavior in games by analyzing their attentional patterns in a basic attentional task. Methods: We recorded eye-movements of 61 participants while performing two different tasks: 1) a visual search task consisting of 120 trials in which participants have to detect, as fast

as possible, a target among several distractors, and an interactive task consisting of 48 one-shot games in which either, neither, or only one of the players involved in the interaction had a dominant strategy. We then grouped participants according to the visual search patterns they made during the visual search task and compare the level of strategic sophistication they adopted in these games. Results: In the visual-search task, the ability to be more flexible in the way attention was allocated lead to higher accuracy and optimality. Interestingly, this ability predicted the level of sophistication adopted in interactive game playing. More specifically, we found a group of participants whose visual-scan path in the visual-search task was driven by the contingent distribution of elements. This indicates that participants were able to adapt their analysis to the specific characteristics of the stimulus. In games, these participants exhibited a more sophisticated visual-analysis that allowed them to choose more optimally. In particular, participants acquired more frequently all the relevant information following a consistent and dynamic pattern of information acquisition that leads to the equilibrium. Participants who exhibited a scan-path that was independent from the actual distribution of elements in the visual-search task deviated more frequently from this visual information acquisition pattern during the game interaction. Conclusions: We found that simple attentional indices of strategic flexibility predict optimality in a visual search task and, more importantly, the ability to best respond to the expected action of the opponent in games. These findings establish a link between basic attentional mechanisms and the level of sophistication in interactive games.

1-K-41   Neural mechanisms of control aversion during social decision making

Sarah Rudorf[1], Thomas Baumgartner[1], Katrin Schmelz[2], Urs Fischbacher[3], Daria Knoch[1]

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When others try to control our decisions, many of us will feel the urge to counteract and thereby reestablish our valued free choice. This control aversion can lead to suboptimal decision making, e.g. opposing laws or health policies, and its antecedents and consequences have been studied extensively. The underlying neural mechanism of how control aversion is integrated into decision making in social interactions, however, remains poorly understood. To close this gap we combined a social decision making task with functional magnetic resonance imaging in a sample of healthy adults. While being scanned subjects allocated money to themselves and varying, anonymous interaction partners. Critically, their interaction partners either let them choose freely (Free condition) or requested a minimum amount to be returned, thereby controlling the subjects' choice options (Control condition). After each decision, subjects rated their feeling of being controlled and negative affects on pictorial assessment scales. The amount to which subjects returned less in the Control than in the Free condition measured individual control aversion. The results show that in the Control compared with the Free condition, subjects report feeling more controlled and return smaller amounts. Their behavioral control aversion also correlates positively with self-reported negative affects. A whole-brain analysis reveals that control over the subjects' choice by the interaction partner is signaled in the temporoparietal junction (TPJ), a brain area that contributes to decision making when a social (or nonsocial) context is relevant for current behavior. Moreover, we find that individual control aversion is associated with specific changes of neural connectivity between the right TPJ and an area in the dorsolateral prefrontal cortex (dlPFC) that has been associated with context-dependent value-based decisions. Taken together, our results suggest that control aversion is associated with the integration of relevant social information into context-dependent decision making.

1-K-42 **Contributions of neural adaptation to value-based and perceptual choice**

Alireza Soltani[1], Oihane Horno[1], Mehran Spitmaan[1]
[1]Dartmouth College

Despite the prevalent use of two-alternative choice paradigms to study different types of decision making, real-life decisions often involve selection among a set of options. The set of options, including the irrelevant options, can alter decision-making processes and result in preference reversal between the relevant options. This set of phenomena, referred to as context or decoy effects, has been extensively studied in value-based choice and has revealed important aspects of valuation and decision processes. Recently, we have proposed that trial-by-trial adjustments of neural representations to the set of presented options can account for some context effects (Soltani et al., 2012). Interestingly, a new study has shown that context effects can also arise in perceptual decision making (Trueblood et al., 2013). Considering the prevalence of neural adaptation in most brain areas, we hypothesized that neural adaptation could contribute to both value-based and perceptual context effects. To test this hypothesis, we conducted an experiment to measure context effects in two different tasks using a within-subject design. In one task, human subjects selected between monetary gambles with different reward probabilities and magnitudes in order to maximize payoff (value-based task). In another task, subjects chose the line with the longest shadow out of a set of slanted lines, and were rewarded based on the size of the shadow (perceptual task). In both tasks, however, subjects were shown three options at the beginning of each trial, and one was removed at the time of choice (phantom decoys). Finally, in order to test the effects of neural adaptation on longer timescales, we measured context effects after increasing the range of option values in another value-based task (high-range manipulation). Firstly, we found within-subject decoy effects for both value-based and perceptual decision-making tasks. However, in the perceptual task, the decoys were effective only when presented next to the more horizontal line. Secondly, we found a significant correlation between the overall decoy effects in the two tasks, indicating that similar trial-by-trial adaptation could underlie context effects in two different types of decision making. Finally, we did not find any difference between decoy effects during the main experiment and high-range manipulation, illustrating that adaptation on longer timescales may not contribute to context effects. Overall, our results extend previous findings on the role of neural adaptation in sensory processing to the realm of irrational choice behavior, and further indicate that adaptation contributes to different types of decision making.

1-K-43 **Independence of Irrelevant Alternatives in Decisions from Experience: A Challenge for Reinforcement Learning Models**

Mikhail Spektor[1], Sebastian Gluth[1], Laura Fontanesi[1], Jörg Rieskamp[1]
[1]University of Basel

Normative decision theory assumes independence of irrelevant alternatives (IIA), stating that the relative preference of two options is independent of the choice set. Previous research demonstrated context effects (i.e., systematic violations of IIA) in decisions from description. They have been demonstrated across different domains, modalities, and even species. Their high relevance for the decision-making literature is reflected in the variety of process models that were proposed in order to explain them (e.g., Roe, Busemeyer, & Townsend, 2001). Yet, it remains unclear whether IIA is violated in decisions where the properties of the options have to be learned by trial-and-error. Such decisions are usually analyzed within the framework of reinforcement learning (RL). Importantly, existing RL models do not predict violations of IIA. The aim of the present study was thus to explore three different context effects in a typical RL setting. A total of 70 participants in three separate experiments completed two

blocks of a repeated-play game with full feedback. Each block contained three options, where two of these three options shared the same outcome distribution across the blocks. The remaining third options were placed in order to elicit one of the targeted context effects, that is, the similarity effect, the compromise effect, or the attraction effect. After completing the two blocks, participants were prompted for explicit knowledge about the outcome distributions in a post-questionnaire. We found that participants' behavior systematically violated IIA. However, these violations were mostly not in line with traditional context-effect research. Instead, they were compatible with the similarity hypothesis, according to which similar options compete with each other for choice shares. These systematic differences to decision from descriptions were further supported by a lack of explicit knowledge about the underlying outcome distributions in the post-questionnaire. We propose a new computational model, the accentuation of differences model (AOD), that generates context-dependent preferences by focusing attention on distinct outcomes. A rigorous model comparison combining post-hoc absolute fit as well as posterior predictive simulations implemented within a hierarchical Bayesian framework resulted in the AOD clearly outperforming RL models commonly used in the literature. The simulations matched the behavioral patterns qualitatively and had a close quantitative fit as well. The present study is the first to demonstrate systematic violations of IIA in decisions from experience as well as to offer a psychologically motivated model to explain such violations.

Monday August 29, 2016

2-F-18   The role of time ambiguity in intertemporal choice

Iris Ikink[1], Jan Engelmann[2], Wouter van den Bos[3], Karin Roelofs[1], Bernd Figner[1]

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Objective: In everyday life, people frequently face choices between a sooner-smaller (SS) reward, e.g., enjoying your favorite high-caloric food now, versus a later-larger (LL) reward, e.g., having a slim figure in the future. Although people often have imprecise information about the timing of outcomes (e.g., when exactly would one have that slim figure?), standard intertemporal choice paradigms typically provide exact timing information. Therefore, the current study investigated how ambiguity in the timing of outcomes influences intertemporal decisions. Methods: We developed a novel intertemporal choice task in which subjects made decisions between SS and LL outcomes in the presence of systematically varying levels of time ambiguity while undergoing functional Magnetic Resonance Imaging (fMRI). Trials presented either exact information about outcome delays (e.g., 5 weeks from now), or imprecise information that ranged between 4 weeks (e.g., 3 to 7 weeks from now) and 8 weeks (e.g., 1 to 9 weeks from now). Time ambiguity was introduced to either the SS, LL or both. To reduce variation in choices due to individual differences in discounting and more effectively isolate the effect of time ambiguity, we used indifference pairs (e.g., pairs of SS and LL outcomes that are matched on subjective value). Results: Participants were significantly less likely to choose an option when its outcome timing was ambiguous compared to when it was precise, indicative of time ambiguity aversion. Consistent with its role in subjective value computations, we found significantly decreased activity in ventromedial prefrontal cortex (vmPFC) during decisions with time ambiguity (compared to decisions without time ambiguity), and this effect was enhanced in subjects that showed greater levels of behavioral ambiguity aversion. Furthermore, we observed increased activation in the intraparietal sulcus (IPS) during decisions with

(versus without) time ambiguity, possibly reflecting increased processing demands under conditions of uncertainty, as this region has previously been implicated in supporting inexact calculations and numerical estimations in probability ambiguity. We are currently conducting analyses to identify brain networks through which time ambiguity exerts its effect on choice (using psycho-physiological interactions (PPI) and mediation approaches). Conclusions: To our knowledge, this is the first study to have investigated ambiguity aversion in the domain of intertemporal choice. Time ambiguity is ubiquitous in the real-world, especially regarding long-term goals, thus time ambiguity likely contributes to short-sighted decisions above and beyond delay discounting.

2-F-20   Assumptions of linear utility systematically bias estimations of impulsivity
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Objective: The study of human impulsivity through measures of temporal discounting (TD) is a widely used approach in the fields of psychology, behavioral economics and more recently in medicine and computational psychiatry. Individual differences in TD are a topic of intense research in these studies, but models of TD traditionally assume a linear utility function in their estimation of discount rates (DRs). However, results from our laboratory have shown that both healthy individuals and patients with substance use disorder deviate from risk neutrality and exhibit high inter-individual variability in their risk preferences. The assumption of linearity of their utility function can lead to differences in the estimation of DRs. In this study we characterized subjects' preferences for risk and time in two separate incentive-compatible choice tasks. We compared two models: a model that incorporates a normative estimate of the curvature of an individual's utility function with a non-normative hyperbolic utility function and a "standard" hyperbolic-only model that does not. Methods: Forty-three participants from the general community were recruited to attend 1-5 sessions during which they completed both a risk attitude task (RA) and an intertemporal choice task (ITC). For the RA task, subjects chose between a certain gain of $5 versus a variable lottery that ranged from $4 to $66 with a 25%, 50% or 75% probability. For the ITC task, participants chose between an immediate monetary reward ($2, $5 or $15) and a larger reward that came with a delay (ranging from $7 to $66 and from 4 to 150 days). At the end of each session, one of the trials from both tasks was randomly selected for realization. We estimated participants' DRs with a "standard" TD model and with a modified hyperbolic TD model with an exponential parameter that accounts for risk preferences. The models were compared using AIC and BIC scores and cross-validated log likelihood comparisons. Results and conclusions: The TD model that includes a risk sensitivity parameter outperformed the "standard" TD model - accounting for significantly more variance in the data. Furthermore, when risk preference deviates from neutrality, the DRs derived from the standard model are systematically different: In risk-averse individuals, impulsivity appears higher with this approach, while DRs appear lower in risk seeking individuals. This finding has important implications for the interpretation of differences across individuals and groups. It is particularly relevant to the ever-growing number of studies concerned with impulsivity in disorders with diverse risk preferences like addiction, ADHD, anxiety and PTSD.

2-K-44   New flavor of the exploration-exploitation trade-off in contextual multi-armed bandit problems
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Concepts from the field of reinforcement learning (RL) have revolutionized human and animal learning

and decision-making. However, applying reinforcement learning algorithms in more realistic multi-dimensional environments is challenging. To battle the curse of dimensionality in such environments the algorithms need to reduce the dimensionality by learning the function between the dimensions and the value of actions. Moreover, exploration-exploitation trade-off acquires a new flavor as explorative choice can be made to learn the function, not necessarily the value of an action. We developed a novel contextual multi-armed bandit (CMAB) task and hypothesized that humans too will rely on learning the structure of the environments to successfully navigate the task and that their their exploration will be guided by the functional knowledge. One thousand four hundred and fifty six subjects participated in five experiments with monetary payoffs. Subject did either a CMAB task where they chose repeatedly between multiple alternatives characterized by two informative features and received outcome feedback on their choices, or a multi-armed bandit (MAB) task where feature information was not presented. Experiments differed in terms of the function governing the relationship between two dimensions and alternative values. To examine the extent of function learning, the CMAB task was followed with an extrapolation test phase where in each trial three new alternatives were shown, generated by the same function. Behavioral analysis showed that CMAB participants performed slightly better than MAB participants. However, inter-individual differences are large and those participants that learn the function better, as judged by the performance in the extrapolation task, perform much better. Access to contextual information can be detrimental as well - benefits are the biggest when functional relationships conform the prior expectations, while they suffer if the relationships are unexpected and prior needs to unlearned. Our examination of choices when switching to new alternatives and choices in the feature space reveal that indeed exploration patterns in the CMAB task are heavily influenced by functional knowledge. We modeled the behavior computationally with three classes of models - naïve RL models that ignore feature information, RL models that use function learning to learn the structure and Gaussian process based models that also perform active learning. These models balance the exploration-exploitation trade-off differently and Gaussian process based models showed to be the best in explaining the exploration patterns observed in our contextual bandit task.

2-F-21	**Disrupting the temporo-parietal junction reveals role of overcoming self-centeredness in delay of gratification**

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The ability to delay gratification is an important cornerstone of individual and societal well-being. Prevalent neural models of intertemporal decision-making focus on the role of a frontal control network in guiding impulsive choices. However, intertemporal choices correlate also with activation in the temporo-parietal junction (TPJ), which is often ascribed a role in social cognition. This raises questions regarding the functional role of the TPJ in temporal discounting, and whether it can be reconciled with social accounts of TPJ functioning. Here, we used transcranial magnetic stimulation (TMS) to assess the role of the TPJ in intertemporal and interpersonal decision-making. Disrupting the TPJ increased discounting of delayed and shared rewards by impairing the ability to overcome the egocentricity bias of the present self. We conclude that a common neural mechanism related to egocentricity bias contributes to temporal and social discounting and that the TPJ plays a crucial role in implementing this mechanism.

2-I-29	**Human Striatum Represents Bayesian Surprise, Not Prediction Error, in Categorization Learning**

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Objective: Humans naturally group the world into coherent categories defined by membership rules. While it is possible to learn these rules using stimulus-response associations, humans also have the ability to explicitly reason about rules. We sought to determine whether the striatum, which reliably shows activation that scales with reward prediction error and is thought to be a part of the brain's reinforcement learning system, would also show prediction error responses in a task where people learn explicit rules. Methods: We acquired functional magnetic resonance imaging data from subjects while they learned the category labels of stimuli with deterministic feedback. The stimuli had three dimension (shape, color, texture), and each dimension had two possible feature values. Subjects learned rules in blocks ranging from simple (e.g., blue stimuli are category 1) to complex (e.g., blue and square or checkered are category 1). We fit a series of reinforcement learning models that learns rules implicitly as well as a Bayesian rational rules model that reasons explicitly over rules. Results: We exploit a difference in the learning signals between reinforcement learning models (reward prediction error) and Bayesian updating (surprise). Reward prediction error is a signed learning signal that is larger for positive than negative feedback. In contrast, surprise in our task was generally larger for negative feedback. In the neural data, we find greater BOLD signal responses to negative relative to positive feedback in both the striatum and ventral tegmental area. This pattern of responses is inconsistent with reward prediction error signaling. Further, we find that activation in the striatum scales parametrically with the Bayesian surprise signal. We propose that the striatum updates stimulus and action values, rather than representing learning signals per se. Although value updating and prediction error are perfectly correlated in reinforcement learning models, rule updating and surprise are not. We demonstrate that the striatum and caudal inferior frontal sulcus (cIFS) activation varies parametrically with rule updating and exhibits functional connectivity during feedback. Conclusions: We conclude that the striatal feedback response does not represent prediction error as part of a reinforcement learning algorithm. Rather, its response scales with the relevant learning signal underlying learning because it is involved in updating a model of stimulus-response demands of the environment. We conclude that the striatum, in cooperation with the cIFS, is specifically involved in updating the values assigned to rules, rather than representation of error.

Tuesday August 30, 2016

3-E-17   The neural correlates of uncertainty in probability updating and risky decision-making

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Our decisions are based on our beliefs about the outcomes associated with our options. These beliefs are shaped by a process of updating based on incoming information. The amount of uncertainty associated with these beliefs depends on the amount of information that was sampled and how that information was processed. Recent theory has proposed broad principles about how these processes might operate, but precise details of its neural implementation remain unclear. Here we propose a novel Bayesian updating model formalizing the process of sampling with free parameters that modulate the strength and weight of incoming information. We hypothesize that individual differences in the free parameters were associated with basic number and ratio sense abilities, and that the uncertainty of the posterior after learning would be reflected in self-reported confidence and bias risk-preferences. We investigated twenty-five male adults (age range: 20-30) with a fixed sampling paradigm (always five

samples of blue or red marbles of an urn) and varied the amount of information during sampling (amount of marbles of each sample) during functional magnetic resonance imaging (fMRI). After each sampling phase the subjects were presented with a gamble. Model-derived uncertainty estimate was applied on a trial-by-trial basis in fMRI analyses. Our results show the Bayesian weighting parameter was significantly correlated with an external measurement of ratio sense, and that the uncertainty was positively correlated to self-reported confidence. Finally, in contrast with ambiguity aversion, we show that in decision from experience higher uncertainty of the posterior is associated with increased risk-preference. Based on the imaging analyses we are able to identify distinct neural signatures that are associated with the uncertainty (Shannon entropy) of the posterior, Bayesian surprise and the magnitude of the update (KL-Divergence). As expected, uncertainty during sampling is associated with activity in a wide network of areas (including posterior cingulate, dorsal anterior cingulate and ventral medial prefrontal cortex (VMPFC)). Interestingly, during the decision phase uncertainty was only represented in an overlapping VMPFC region. These results provide evidence that the cognitive mechanisms underlying belief updating in humans can be described well within a, slightly modified, Bayesian framework. Furthermore, they suggest that deviations from optimal Bayes may be calibrated to the quality of earlier representations of numbers and ratios. Furthermore they suggest that the VMPFC may have a specific role in representing uncertainty in relation to decision-making.

3-E-18   Computational substrats for the limits in human probabilistic inference

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Uncertainty is a central feature in many decisions we face. Making decision under uncertainty often requires the organisms to have accurate knowledge about probability distribution over possible outcomes. However, information about probabilities can come from different sources, making source integration a key computational problem. In this study, we investigated how humans combine prior experience and current information about reward probability when making decisions. In particular, we asked how the reliability of these two sources of information affect the weights assigned to them in probabilistic inference. Method. In a lottery decision task, on each trial, subjects were presented with two visual stimuli - one associated with past experience on rewards (prior knowledge) obtained in a previous session and the other a new and independent piece of sensory evidence for reward probability (likelihood information). In order to maximize rewards, subjects should integrate both sources of information by taking into account the reliability of each source so as to compute the optimal estimates of probability. Results. Twenty-eight subjects participated in the experiment. At the behavioral level, we found that subjects were more sensitive to changes in the reliability of likelihood information than prior knowledge. Such tendency contributed to a unique pattern of suboptimal performance: When prior information was highly reliable, subjects exhibited patterns similar to base-rate neglect - they underweight prior information. In contrast, when prior information was highly variable, subjects achieved near-optimal integration. Using fMRI, we found that brain activity in the central orbital frontal cortex (cOFC) and the anterior insula were positively correlated with the reliability of the prior distribution, while the medial prefrontal cortex (mPFC) represented the reliability of the likelihood function. Furthermore, independent region-of-interest analyses suggested that cOFC not only represented the group average of subjective weight (SW) subjects assigned to likelihood relative to prior information, but also the individual differences in SW. These results indicated that OFC reflects the reliability-dependent asymmetry in information weighting and provided insights into the computational substrates for the limits in human probabilistic inference.

3-L-47   **Neural substrates of group-based hierarchy and inequity preferences**

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Objective: Social dominance orientation (SDO) is a preference for group-based hierarchy and unequal distribution of positive social rewards between dominant and subordinate social groups. Group-based experiments have shown that individuals with high SDO act to maximize the relative payoff difference between their own and other groups, suggesting an effect of group identity on group-based inequity. It remains unclear whether SDO generated inequity is the result of group competitive interactions or of individual preferences for inequity. Here we demonstrate a relationship between SDO and prosociality in anonymous social interactions, and provide evidence that SDO is associated with the structure of DLPFC, a brain region involved in deliberative control. Methods: We acquired brain structure and behavior of 470 participants. SDO was measured with the SDO questionnaire. Social Value Orientation (SVO), a personality measure of individual preference for equity, was assessed with a task of reward distribution between self and others. Subjects played anonymously the Dictator Game (DG, dictator role), Ultimatum Game (UG, proposer role) and Trust Game (TG, trustee role), and responded personality questionnaires of Machiavellianism, empathy, social mindfulness, trust attitude, and F-scale. Results: SDO negatively correlated with SVO. In the SVO task, participants with high-SDO gave themselves the larger reward and those with low-SDO made more equal reward distribution. SDO negatively correlated with reward transfer size in the DG and TG. The UG-DG transfer difference, considered a measure of strategic social behavior, had a marginal positive correlation with SDO. The relationship between SDO and behavior in the DG, UG, and TG disappeared after controlling for SVO. The VBM analysis revealed a positive correlation between SDO and volumes of the DLPFC, VLPFC, and cerebellum. Among the personality measures, only social mindfulness negatively correlated with DLPFC and VLPFC volumes. Conclusions: The behavioral results show a strong relationship between SDO and individual inequity preferences in the absence of group competition. SDO was also related with self-interested decisions in the DG and TG. The strategic social behavior suggests that inequity generated by SDO is not indiscriminate. The positive relationship between SDO and the volume of the DLPFC suggests that SDO and related self-interested and inequity generating decisions are controlled by deliberative processes.

3-L-53   **What is beautiful is trustworthy - neuroanatomic and -functional correlates of the Halo effect**

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Physically attractive persons are perceived to possess more socially desirable personality traits, such as trustworthiness, than physically unattractive persons; an effect also referred to as Halo effect. Although this phenomenon is widely observed in human society, its neural basis is uninvestigated. Also, it is unclear whether this is a mere momentary bias during the judgement situation or a more stable, hardwired cognitive ability. Here, we investigated the neuroanatomical and -functional correlates of the Halo effect in 33 (19 females) healthy subjects using magnetic resonance imaging, while subjects were viewing faces. The individual degree of the Halo effect was assessed 1) immediately after the scanning and 2) 5 years later, with which we demonstrate the extreme persistence and stability of the Halo effect (r=0.62; p<0.05). Supporting this behavioral persistence, a VBM analysis revealed that the grey matter density of amygdala significantly predicts the individual differences in Halo effect. Furthermore, we

show that the amygdala changes its functional connectivity with the striatum when subjects are viewing attractive vs. non-attractive faces. This amygdala-striatal connectivity change is significantly modulated by individual differences in the Halo effect. The Halo effect is thought to be a major candidate mechanism leading to stereotype. Our results powerfully demonstrate the persistence of the Halo effect, how it is anchored in the brain structure and its impact on brain function during social cognition.

3-L-49   **Distinguishing different psychiatric populations based on a social hierarchy paradigm**
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Introduction Anti-Social Personality Disorder (ASPD) and Borderline Personality Disorder (BPD) are psychopathologies characterized by profoundly aberrant interpersonal behaviour. They strongly affect the lives of both individual patients and those around them. BPDs and ASPDs share many behavioural characteristics, such as impulsivity and difficulty in sustaining long-lasting social relationships, and although they are considered different disorders, the distinction between them is sometimes blurry1. Amongst clinicians and scientists there is a growing interest in novel approaches to psychiatric disease classification that allow for better understanding and distinction of psychiatric diseases, based on potentially quantifiable traits. Here, we use a Social Hierarchy decision-making paradigm and apply computational models to the obtained behaviour to understand better the differences between BPDs, ASPDs and controls, and how these diseases impact social decision making. Methods As part of a large-scale computational psychiatry program, 159 BPDs, 12 ASPDs and 103 healthy controls (total n=274) participated in a multi-round social exchange paradigm, the Social Hierarchy (SH) game. In each round of the SH game one of the players ('alpha') receives a given sum of money and decides how to split it with the other player ('beta'). Then, the beta player has the chance to 'challenge' the alpha's position. If there is a challenge, both alpha and beta decide by how much to challenge (beta) or defend (alpha). Whoever spends the most assumes the alpha position in the next round. The SH game is played for 30 rounds, always with the same opponent (here a computer algorithm mimicking a real person). Results We found that ASPD participants spent significantly more on average on contests and left their opponent with lower final earnings compared to both controls and BPDs. For the BPDs, model agnostic approaches did not show them to differ significantly from healthy controls, but a logistic regression model relating challenge decision to amount transferred showed BPDs had a higher baseline tendency to challenge and were more sensitive to the amount of money transferred by the opponent. We also started doing cross-validated model-based analyses of participants? behaviour and are obtaining interesting results. Conclusions Our results suggest that ASPDs value social dominance more than healthy controls and BPDs, whilst the latter are particularly sensitive to social signals. These results suggest that ASPD and BPD may be two actual separate diagnoses, and offer promising avenues by which different psychiatric disease states could be distinguished at the mechanistic level.

Poster Abstracts

A – Emotion & Affect

1-A-1   The relationship between entrepreneurial and parental love

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Objective: Are experiences of an entrepreneur towards his/her own firm similar to the experiences of parents towards their children? Here we studied underlying brain mechanisms using functional MRI (fMRI), specifically testing the hypothesis that male entrepreneur's emotional experience and brain responses during viewing his own firm resembles those of fathers towards their own children. Methods: Altogether 42 healthy male subjects participated in the fMRI study (21 entrepreneurs and 21 fathers). Before the fMRI session, the subjects filled out questionnaires on affect intensity, sense of closeness of the relationship between the father and his child and between the entrepreneur and his venture, confidence, and socioeconomic and entrepreneurship / parenthood background. We measured the brain activity while entrepreneurs viewed pictures on their own and of a familiar firm, and while fathers viewed pictures of their own and of a familiar child. Results: According to the behavioral results, entrepreneurial love is strikingly similar to paternal love. At the neural level, caudate nucleus, a brain structure associated with processing of rewards, was similarly activated in the entrepreneurs and fathers when viewing their own ventures and children. Individual differences in the closeness of the relationship between an entrepreneur and his firm influenced the pattern of activation in the posterior cingulate cortex (PCC), temporoparietal junction (TPJ) and dorsomedial prefrontal cortex (DMPFC): the entrepreneurs who self-rated as being very closely attached with their venture showed similar suppression of activity in the PCC, TPJ and DMPFC as fathers during viewing pictures of their own children vs. familiar children. In addition, individual differences in separately measured confidence trait influenced neural encoding of both paternal and entrepreneurial processing. For under-confident fathers, a picture of one's own child was associated with stronger activation and for overconfident fathers with weaker activation in the amygdala. Similar pattern of activation, yet more widespread in the emotional processing network, was observed in entrepreneurs suggesting similar neural basis for increased sensitivity to threats and potential risks concerning one's venture and child. Conclusions: Our results show that the strong attachment entrepreneurs can have to their venture is reflected in the same brain areas as the attachment between a parent and a child. We conclude that both entrepreneurial and parental love is reflected in reward processing in the caudate nucleus and supported by neural networks associated with emotional processing and social understanding.

1-A-2   In the mood for Cheetos but Pringles will do: craving multiplicatively transforms the value of related snacks

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Background: Craving is a widely discussed and studied desire for a specific consumable (e.g., a cigarette or chocolate). Despite its role in the maintenance of addictive behaviors, we know surprisingly little about what craving is and how it biases our choices-and it is a concept almost completely absent from formal analyses of choice. Here, we characterize how craving is reflected in the values subjects place on snack foods in a task with real consequences for both when and how these value judgments are made. Methods: Subjective values for a variety of snacks were derived in a willingness to pay (WTP) task with

interspersed 'desire' ratings, which carried real consequences or no consequences, respectively, for which if any snack(s) subjects got at the end of the task. To incentivize subjects to continuously report the value they placed on each snack in each moment, we employed a constant hazard rate which determined every ~3 min over 1 h if the task would end or not. After a baseline period, subjects underwent a brief craving induction procedure similar to that used in drug addiction studies in which they were exposed to the sight and smell of one of three snacks (randomly assigned snickers, cheetos, or coke), before returning to the task. A different set of subjects completed a version of the task in which we additionally varied snack quantity, allowing us to estimate a utility curve for each snack at each ~3-min time bin (study 2). Results & Conclusions: Craving transiently increased the value of the induction-specific snack in both nonconsequential desire ratings and consequential WTP decisions. Interestingly, WTP for subjectively similar snacks also increased. At the other end-the subjectively most dissimilar snacks-instead tended to reduce in value. We observed these effects irrespective of the identity of the craved snack, suggesting they did not simply reflect changes in hunger or thirst. The magnitude of increase in WTP for the craved snack was not the same for everyone. Instead, craving supra-additively transformed baseline WTP: the craving effect was stronger for those subjects who were willing to pay more for the craved snack at baseline. We tested the exact form of this transformation in study 2. Craving increased the slope but did not affect the curvature of the utility curve, pointing to a multiplicative transformation of the value of the craved snack akin to gain control. We recapitulate the set of findings from both studies in a model of craving that incorporates risk aversion, time, and feature similarity. More broadly, results reveal a gradient of value representation in the brain upon which craving may act to flexibly guide choice.

1-A-3   Transport and emotion: the contribution of neurosciences
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With the exception of fear felt due to the insecurity of making a trip or stress linked to driving, the link between transport and emotion is not something that immediately comes to mind. However, one not only travels because of the utility of his destination but also because one is motivated by psychological criteria (Dittmar, 1992; Mokhtarian and Salomon, 2001; Ory and Mokhtarian, 2009). This psychological motivation and the role of context are also at the heart of behavioural economics. Using the limits of standard economic models, behavioural economics studies the role and the place of nudges and context via affects in the agents behaviour (Kahneman and Tversky, 1979, 2002; Camerer et al., 2003; Thaler and Sunstein, 2003, 2008). This growing interest in affects can also be seen in the field of transport (Jakobsson-Bergstad et al., 2011; Abou-Zeid and Ben-Akiva, 2012; Etterna et al., 2012; Friman et al., 2013). These advances leads to deeper questioning on the best way of foreseeing and evaluating the satisfaction of individuals and, finally, their well-being (Easterlin, 1995; Diener et al., 1999; Stutzer, 2004). But to our knowledge none of these works has referred to another innovative contribution of behavioural economics, that of the use of neurosciences. The basic principle of neurosciences is that it focuses more on investigating the brain directly rather than the person (Camerer et al., 2004; Fehr and Rangel, 2011). On the basis of a literature analysis, the objective of this paper is to take stock on taking emotions into account in transport and to show how the use of neurosciences could permit going further in gaining new knowledge about them. Even if it implies very costly research and their own problem of interpretation, neurosciences allow not only a more precise analysis inside the brain but also a helpful means to identify brain zones activated by emotion generated by transport. This is a way for capturing emotion effect more easily translated into aggregated understanding of the actors' behaviors'

than psychometric questions. It is clear that this path of investigation opens up a wide range of new opportunities for research. We therefore propose an agenda for research into the relation between emotions and transport that could benefit greatly from the toolbox offered by neuroscience. We organize this agenda by identifying the main issues currently facing the area of transport and in which emotions should be taken into account. For example, we show that emotion, identify by insula activation, can be taken into account in modelling transport demand.

1-A-4   Neural substrates of stimulus value in binary choice about the emotional expressiveness of sad faces

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Objective Neuroeconomical studies of choice have identified neural correlates of gradients of preference that putatively based on a fundamental, more general computational process of value comparison. To date, however, the relevance of this model in the appraisal of emotional stimuli has not been investigated. Here, we pursued this issue by regressing the fMRI signal on the gradient of choice (difference in the subjective value of two options) when assessing the amount of sadness expressed by human faces. We hypothesized that the activation associated with this gradient would provide evidence on the existence of neural substrates related to the recruitment of this fundamental computational process in detecting sufferance in conspecifics. Methods N=17 individuals were scanned while choosing the saddest of two faces in each trial. Faces were presented in a range that spanned completely neutral expressions at one end and very sad expression at the other end. We ranked the degree of sadness of each face according to the choices of individual participants, and regressed the trial signal on the difference between these ranks (gradient of choice) by specifying it as a 'parametric modulator' of the BOLD trial regressor. Results The gradient of choice for the saddest face in the trial was significantly associated with activation in the left insula (-36 0 14, p= 0.03, peak-level corrected) in a large cluster that extended into the rolandic operculum and the postcentral gyrus (p< 0.001, cluster level corrected). This effect was accompanied by a much weaker activation on the right side. Also significant was a cluster of bilateral activation in the middle cingulus (-8 -26 46, p<0.001, cluster-level corrected) and in the precuneus (-4 -52 16, p<0.001, cluster-level corrected). No activation was noted, even at uncorrected significant level, in the amygdala or in the medial orbitofrontal cortex. No significnt activation was noticed in the regression of the sum of the degree of sadness scores. Discussion The medial orbitofrontal cortex, the area primarily associated with subjective preferences, was not active in the present study. However, there was a significant activation of its posterior counterpart in the posterior cingular gyrus/precuneus, also noted in meta-analyses of neuroeconomical choice. There were also activations of secondary somatosensory areas, which are reported in studies of appraisal of pain. We conclude that the use of a choice paradigm may to clarify mechanisms of motivationally sensitive decisions in the emotional and social domain, such as those depending on the detection of sufferance in conspecifics.

B – Individual & Lifespan Differences

1-B-5   Age-related differences in social risk behavior are associated with dopamine synthesis capacity in the striatum

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Objective: Risky economic behavior undergoes significant age-related changes over the course of the adult lifespan. However, little is known about the underlying neurobiological mechanisms. In the present study we examined the relationship between striatal dopamine synthesis capacity and risky cooperative behavior using the stag hunt game. We predicted that a reduction in striatal dopamine synthesis capacity is linked to increased risk-taking in older adults. Methods: Young (n=27, age: 20-32) and healthy elderly adults (n=27, age: 62-80) were asked to play variations of a 2x2 stag hunt game with a fixed partner (no feedback). In the game, players chose between a cooperative (risky) strategy and a non-cooperative (safer) strategy. The stag hunt games differed with regard to the social risk level. In each stag hunt game, we also elicited the participants? beliefs about the likelihood that their partner chose the cooperative (risky) strategy. Positron emission tomography (PET) was also performed in 25 of the elderly adults to assess the synthesis capacity of dopamine in the striatum using [18F] fluoro-l-dopa (f-DOPA). Results: Behaviorally, we found significantly increased cooperation rates in older adults relative to young adults in stag hunt games where choosing the cooperative strategy is highly socially risky. The same age-related difference was observed for the beliefs. At the neural level, the age-related difference in cooperation rates was associated with a reduction in dopamine synthesis capacity in the right putamen. Conclusions: Our findings show that older adults in comparison to younger individuals demonstrate a reduced ability to accurately estimate the level of risk during social interactions. This may be due to an age-related reduction in striatal dopaminergic function. Acknowledgements: This work was supported by the SFB 779-TP A07.

1-B-6   Changes in sensitivity to risk across the lifespan

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Objective: As the aging population continues to increase so does the pressing need to better understand the aging process. In the domain of decision making, there is considerable disagreement on how risk taking changes across the lifespan. This lack of consensus has several potential sources, including inconsistencies in decision making task characteristics, the presence of decision processes confounded with risk taking, and the practice of comparing younger adults to older adults, excluding other intermediate age groups. To address this, in the current study we examined the effects of age, measured as a continuous variable spanning young, intermediate, and older ages, on decision making, as indexed by independently quantifiable and dissociated decision parameters--sensitivity to risk, loss aversion, and choice consistency. Methods: A total of 125 participants ranging in age from 20 to 69 years completed a risky monetary choice task on Amazon Mechanical Turk. We recruited an equal number of participants for each decade bin (e.g., 25 participants aged 20-29, 25 participants aged 30-39, etc.). In the risky monetary choice task, participants made 150 choices between a risky gamble and a guaranteed alternative (Sokol-Hessner, et al., 2009; 2013; 2014). For 120 of the trials participants chose between a mixed-valence gamble (i.e., a gamble with equally likely positive and negative possible outcomes) and a guaranteed alternative of $0. On the remaining 30 trials, participants chose between a gamble with equally likely positive and zero possible outcomes and b) a positive guaranteed alternative. Monetary amounts varied across trials, though the probability associated with gamble outcomes was always p=0.5. Participants were fully informed of, quizzed on, and practiced in all contingencies and probabilities during the task prior to data collection. Based on prospect-theory (Tversky & Kahneman, 1992) each participant's choices were then modeled to quantify loss aversion, risk attitudes, and choice consistency. Results: Age was predictive of sensitivity to risk such that as age increased individuals

displayed more risk aversion (i.e., higher rates of diminishing marginal sensitivity). Importantly, the choice set design in combination with the modeling procedure applied allowed the identification of risk aversion as separate from loss aversion or choice consistency. Conclusions: The current findings highlight the importance of decomposing decision making into discrete parameters and using these innovative tools to gain a better understanding of the age-related changes that occur in decision making.

1-B-7   Adult Age Differences in Neural Representations of Value in Time, Probability and Effort Discounting Tasks

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Objective: In the present study we examine adult age differences in choice behavior and the neural representations of subjective value in tasks where monetary rewards must be integrated with one of three discounting factors: time, probability and physical effort. Methods: 73 healthy participants between the ages of 22 and 83 (N=32M/41F) completed 3T fMRI studies at Vanderbilt University. Participants made choices between either (1) a smaller magnitude reward with a shorter time delay / higher probability / lower level of physical effort required and (2) a larger magnitude reward with a longer time delay / lower probability / higher level of physical effort required. For each task, participants were compensated with the payout from one trial. Subjective values were computed using individual subject discount rates estimated using a hyperbolic discount function. In addition to examining the integrated representation of subjective value, additional models examined the separate representations of reward magnitude and either time, probability, or effort. Results: Contrary to prior studies, we found no significant relationship between age and discount rates - preferences for short time delays, high probability, or lower physical effort. There were also no age differences in the neural representation of subjective value in any of the tasks. However, age differences emerged when examining the representation of reward magnitude and each discounting factor separately. There was a significant negative effect of age for the representation of probability in the left midcingulate cortex (MCC) such that older age was associated with lower representation of probability. During the physical effort task there was a significant negative effect of age for representation of reward magnitude in the left middle frontal gyrus (MFG) such that older age was associated with lower representation of reward magnitude. There was also a significant positive effect of age for the representation of effort in the right insular cortex (INS) such that older age was associated with greater activity. There were no age effects in the representation of time or reward magnitude in the time discounting task. Conclusions: These results suggest that age differences in neural representation only appear when subjective value is decomposed into reward magnitude and each individual discounting factor. Despite age-related differences in the representations of reward magnitude and each discounting factor, the lack of age differences in the representation of subjective value and behavior suggest that these value-related signals are integrated similarly across adulthood.

C - Finance

1-C-8   Cognitive Capacities, Trading Styles and Experimental Asset Market Bubbles

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We propose that observed heterogeneity in asset market trading behavior is the result of two distinct,

non-convertible mental capabilities: analytical (``quantitative'') abilities and mentalizing (``perspective-taking'') abilities. We develop a conceptual framework of mental capabilities which yields testable predictions about individual trading behavior, revenue distribution and market dynamics. Individuals will trade most successfully if and only if they have both capabilities. On the other hand, a person who can mentalize well but has poor analytical capacities will suffer the largest losses. Whereas those traders with only analytical capacities, will trade along the fundamental value and thus avoid losses but also miss trading gains. As a consequence, being endowed with just one dimension does not assure trading success. We test these implications in a tightly controlled laboratory environment, where we first independently elicit subjects' capabilities in both dimensions and then conduct a standard asset market experiment. The empirical findings can be summarized in four key results: (1) The measures of both mental capacities are independent. (2) Analyzing the trading gains of the asset market, we observe that those subjects who performed well in both dimension earned the highest trading profits, while being better at only one cognitive capacity does not increase trading gains; moreover, a one-sided specialization on mentalizing capabilities leads to substantial losses. Thus, focusing on just one of the two dimension masks important heterogeneity across cognitive type mixes. (3) These difference in trading gains are the result of heterogeneous trading patterns dependent on the cognitive capacity mix. (4) These different trading styles affects the market dynamics and by switching from the net-buying to the net-selling the asset between period 6-8 as a group the subjects being good in both dimensions mainly initiate the turning point. On the market level we find that a higher share of A-high types reduce the bubble size. In sum our results uncover a structure that was hidden in previous, one-dimensional approaches that mostly aimed at the analytical dimension of mental skills, e.g. beauty contest as measure for strategic sophistication. Which speaks in favor of applying our conceptual framework and the screening method to other (economic) decision situations and games in order to explain observed heterogeneous behavioural outcome. The findings are also relevant on firm-level policies to select successful traders or on macro-level analysis to understand sources for the dynamics during asset bubbles.

1-C-9   Neural correlates of financial decisions during a real Direct Access Trading (DAT) session: an fMRI study

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Objective:While financial decision making (DM) has been barely explored, no study has so far investigated the neural correlates of individual decisions taken by professional traders, involved in real stock market, using their own financial resources, and not virtual money. We sought to detect to what extent the activity of different brain areas is modulated by factors like age, expertise, psychological profile, and, eventually, size and type (Buy/Sell) of stock negotiations made using DAT electronic platforms to trade directly in the market. Methods: 21 male, high performing, professional traders, were connected to the Italian Stock Exchange Market, via a DAT electronic platform, and to their personal bank account while undergoing fMRI in a 3.0 Tesla scanner. The total trading activity was recorded and synchronized with the fMRI signal acquisition, in order to quantify BOLD signal changes observed in the 10 sec timeframe immediately preceding each financial decision, and contrast them to the independent variables of interest. Results: All subjects completed the fMRI sessions, performing a minimum of 20 stock negotiations (mean: 45,1 35,9; range: 20-140), whose value ranged from 169 to 10445 Euro. During trading, a significant activation of both cortical (parietal cortex-BA40, posterior cingulate cortex, right insula, orbitofrontal gyrus-OFC, ventromedial prefrontal cortex-vmPFC and dorsolateral prefrontal

cortex-dlPFC) and subcortical brain areas (left N.accumbens-NAcc, and left caudate nucleus) has been found. An inverse relationship between age and left NAcc activation (r2 =,408), and between the trader expertise and the vmPFC activation (r2 =,239) has been found. The total amount of each transaction is inversely related to the BOLD signal change in the dorsal striatum, irrespective of the type (Buy or Sell), while parietal area shows stronger activation for higher transaction value, during Buy, though not Sell. Finally, the higher the activation of the vmPFC and dlPFC the greater the proportion of filled transactions. Discussion: The results of this study confirms the role played by the parietal area, the OFC, and the right vmPFC in financial DM. Moreover, other subcortical areas have been found to be significantly involved in trader's decisions, strengthening the hypothesis that a large part of financial decisions is preceded by unconscious, automatic processes and influenced by intuitions and heuristics. This is in contrast with the economic traditional vision and Modern Portfolio Theory proposed by Markowitz (1952) according to which agents are rational and decide on the basis of cost-benefit analysis and expected reward and variance parameters

D - Consumer Behavior & Marketing

1-D-10   Which brands go together? Neural response patterns during visual imagery of consumer brands are associated with subsequent evaluations on co-branding

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Objective: Companies invest a lot of money in creating and maintaining a desired 'image' for their brand. The strength of this brand image has been shown to be highly predictive for the brand's success. In the present study, we tried to decode these images from brain activations when consumers engage in free visual imagery of consumer brands by comparing them to neural responses to a large set of naturalistic stimuli depicting various social contexts. We used this information to predict how consumers perceive brand image similarity (e.g., how related are the personal care brand Axe and the apparel brand Abercrombie and Fitch?), and to examine whether neural representational similarity of a given pair of brands predicts the perceived suitability of co-branding. Finally, we tested if inter-subject reliability of neural representations associates with self-reported brand image vividness. Method: Before scanning, 38 participants were asked to freely construct, for each of 14 well-known brands, a mental image that they thought depicted the typical social context associated with the brand (e.g. with Dell the image could be working in an office). Inside the scanner, they were instructed to visualize these images upon presentation of brand logos (14 brands × 6 repetitions). In a separate scanning block, participants viewed 112 pictures depicting different social contexts (i.e., family, work, party and romance). Outside the scanner, they made similarity judgments by freely and iteratively arranging 14 brands on a 2D grid. About one week later, they reported via an online survey their brand perceptions and evaluated the suitability of co-branding of randomly drawn brand pairs. Results: Within each subject, a support vector machine classifier for each social context (e.g., family) was trained on neural responses to naturalistic stimuli, and then applied on neural responses during brand imagery (e.g., Disney). Classification probabilities for each brand were significantly associated with self-reported brand perceptions. Moreover, we constructed brand profiles based on their neural representational distances to the set of naturalistic stimuli. Similarities of these brand profiles correlated with individual judgment of brand image similarity and perceived suitability for co-branding. Inter-subject reliability of brand profiles also correlated with self-reported brand image vividness. Conclusion: This study demonstrates a novel approach to infer both content and strength of brand image - a complex cognitive construct - from

neural responses. The findings have potential real-world implications for marketing decision making on co-branding and brand extension.

1-D-11   **Neural measures of evoked emotions in predicting advertising effectiveness**

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Objective: Conventional marketing research to assess consumers processing of advertising typically uses questionnaires and focus groups. Increasingly, 'neural focus groups' are becoming more popular to evaluate and test advertising. In the present study, we tried to capture the emotional state that print advertisements evoke by means of measuring EEG. In addition, we investigated whether these evoked emotions were able to explain consumers' attitude towards the ads in the population at large. Methods: Brain activity was measured using EEG for a group of 31 people while they performed two tasks. The first task was a localizer task aimed at localizing the processing of valence and arousal. Stimuli consisted of 100 photos from the International Affective Picture System (IAPS) selected from the extremes of both the valence and arousal dimension. In the second task brain activity was measured in response to viewing print advertisements. The 150 ads pertained to five product categories: cars, gadgets, food, beauty, and fashion. A separate panel of 1260 people rated the notability of the ad, attitude towards the ad, and overall quality of the ad. Results: Analysis of variance revealed that the arousal level of the IAPS pictures affected the power of the EEG in the alpha band for a cluster of posterior-central electrodes. This cluster was used in subsequent analysis as our arousal Region of Interest (ROI). Valence level did not affect the power of the EEG. Using logistic regression, we next estimated participant specific arousal coefficients, where brain activity sampled from the arousal ROI served as a predictor, and arousal level of the IAPS picture category served as the response variable. Then, we used these coefficients and data from the arousal ROI from the print ad task to estimate the level of arousal that each print ad evoked. Finally, we used these estimated arousal levels per ad to predict population-level measures of ad effectiveness. We found that arousal was positively related to ad notability, and negatively to attitude towards the ad and overall quality, even after controlling for other ad features. Conclusion: Advertisements' evoked level of arousal as measured in a relatively small sample using EEG is indicative of consumers' attitude towards the same ads in the population at large. Neural measures may thus provide a means for pre-testing advertisements.

1-D-12   **A classification of brand evangelism through temperamental and psychological measures**

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Objective. Brand evangelists are committed consumers who have a strong emotional connection to a preferred brand and spread the message about it to others. It is not straightforward what is the psychological characterization of these consumers and which are the roles of positive and negative word of mouth (WoM) in their influencing behaviors. To settle this question we aim to separately analyze Hate Evangelists (HE, characterized by a relatively strong negative WoM compared to the positive one) and Love Evangelists (LE, who show the opposite traits). Starting from these overt behaviors, we aimed at identifying the psychological profiles of each group using a set of validated personality questionnaires about temperamental and biologically-based traits and at comparing this approach to conventional

marketing characterization. Methods. 214 students (104 male, age 22±3 years) were enrolled in the study. Participants were first asked to choose the preferred brand for several product categories and to state which corresponded to their favorite brand. Then, participant answered a list of questions about brand attitude, purchase behavior and about own psychological profile and personality traits. Participants were classified based on two dimensions corresponding to positive and negative WoM and a probit regression model was used to identify the relative weight of each item within the corresponding dimension. Personality traits and purchase behavior of the groups that emerged with the whole sample were compared (with t-test and Mann-Whitney test) to identify which characteristics better connoted each cluster. Results. Probit model classification identified a cluster of 38 core evangelist (CE) characterized by higher positive and/or negative WoM, as compared to general sample. CEs were divided in two subgroups, LE and HE, according to prevalent kind of WoM. Compared to the general sample, CE showed a significant attitude toward routinely purchase and attention to the quality of products besides the classical trust index to preferred brand. Personality questionnaires distinguished LE - that showed a major emphatic consideration for fictional objects and situation, and a biological predisposition to positive reward -, from HE that were characterized by minor concern about public judgment and more a impulsively and perseverant attitude. Conclusions. Through the differentiation of WoM behavior and the support of psychometric scales, various personality nuances of brand evangelism were isolated, so to overcome the current classifications as derived from traditional studies, based on a single brand and adopt marketing scales exclusively.

E – Risk & Uncertainty

1-E-13   Traders' Decision-Making Processes: Results from psychometric tests and investment simulation

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The objective of this article is to identify, with the aid of an psychometric questionnaire (Vallerand and Big Five), that traders do consider emotions in their decision-making process when it comes to making a financial investment. In addition, the authors managed to appoint some behaviour biases, especially towards anchoring, confidence and risk preferences towards market financial. The aim of this contribution is to strengthen the methodological link between economics / finance by using a psychometric approach. It is widely accepted that within behavior finance people use prices as anchors, then moves of individuals can be anticipated through a determined time anchor based on market sentiment. Kahneman (2003) provided two types of processing, System 1, which is similar to associative thinking, and system 2, that works at a slower speed and is much more volatile, being subject to conscious judgments and attitudes. METHODOLOGY: A total of forty volunteers, equally divided into two samples were recruited - male and female financial market professionals, also called traders. Volunteers participated in a simulation of investments in the Sao Paulo Stock Exchange - BM & FBovespa - and had to respond to two questionnaires (Vallerand and Big Five) before the simulation. The model of the Big Five factors is a model best known among the factor theories, where factor I called Socialization; the II factor is Extraversion / Introversion; 3) III factor is known as Conscientiousness; 4) IV factor called Emotional Control and 5) the factor V is Intellect. The questionnaire Vallerand relates to additional personality aspects of the volunteers (conservative or liberal). Thus, the purpose of this study was to characterize biases patterns associated with the decision to buy, sell or hold a stock through a cross section regression and Cronbach's coefficient (assessing the consistency of the analysis). RESULTS: Cordiality and emotion were featured in the Big Five Questionnaire as well as External Control, Market

and Introspection to Vallerand in traders' group. However, unsurprisingly, the group of Traders is permeated by intellect, possible reflection of the knowledge of finance. The regression between the values obtained in the portfolio and personality data corroborates our assumption that: (1) Investment reflects the diversity of strategies in the simulation (and also some mistakes); (2) a self-demotivation points towards penalty and last, but not least , (3) The non-relevance of emotional control and the market shows the dominance of the intuitive side.

1-E-14   Social modulation of risky behaviors

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Objective Risk tolerance has been shown to increase in the presence of risk-tolerant others, which can lead to negative economic and social outcomes. Hypothesized mechanisms to increase a person's risk tolerance include: 1. Their beliefs that others may be willing to tolerate more uncertainty (social beliefs) and 2. Their desire to match others' risk behaviors in the current context (social context). We developed two social variants of the Balloon Analogue Risk Task (BART; Lejuez et al., 2002), in order to separate the effects of social beliefs and social context on individuals' risk tolerance.   Methods In groups of 5-12, 29 experimental sessions were run in which 1 participant underwent fMRI and played other behavioral participants outside the scanner in real-time (n=159). We used a multiband EPI acquisition with a TR of 0.46 which provided a better temporal resolution to disentangle different aspects during social interactions. Social BART participants played against each other by pumping a balloon and cashing in above the other player without popping. To measure the effects of social beliefs, players were allowed to see the opponent's identity but actions during the trial were hidden. To measure the effects of social context on risk tolerance, participants could see all of the second player's behavior, but were not shown who the second player was. As a control to our social manipulation, participants also played both versions of the game with a computer simulated player (CSP). Results Our preliminary results indicate that risk tolerance is significantly modulated as a function of the two different types of social interaction. Preliminary fMRI analyses show that different pieces of what is traditionally considered the 'social brain' are independently associated with risk tolerance modulated by social context and social belief. Conclusions Risk preferences are likely modulated by both social beliefs and social context, with both being supported by independent neural substrates. The BART is one of the few risk tasks that has reliably predicted participants' risk behavior in a wide variety of decision domains. Additionally, our sample size provides sufficient power to have greater than 80% confidence of identifying moderately sized relationships between social risk behavior and real-life risks, as measured by an extensive questionnaire probing various risk-related activities.

1-E-15   Decomposing risk representation in parietal cortex

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OBJECTIVE: Parietal cortex (PC) has consistently been implicated in decision making under risk or uncertainty. Regions in PC have also been linked to attention and numeracy, processes that likely play a role in risky decision making. A common neural circuitry may support numeracy processing and the numerical components of risk--magnitude, probability, expected value (EV)--in PC. METHODS: We tested

this hypothesis using fMRI of 61 participants during passive observation of probabilistic gambles. Magnitude and probability were fully crossed and each of 20 combinations appeared in six trials. After specifying the space of possible models for the risk components, we used a model selection procedure to identify the most likely fit for the data. We were particularly interested in model fit in two a priori regions of interest (ROI) in PC: bilateral 10-mm spheres centered on peak activations for risk processing (Weber & Huettel, 2006) and the Neurosynth reverse inference map for the term "numbers" (Yarkoni et al., 2011). RESULTS: Magnitude was best represented in PC as a logarithmic compression of prize value (p<0.05, corrected), consistent with evidence demonstrating scaling of numerical information in non-human primates. Moreover, contrary to some reports, we found strong evidence for a quadratic representation of probability in both ROIs (p<0.05, corrected). EV was not represented in PC. CONCLUSIONS: We found that the components of risky gambles were processed differentially in PC, with overlapping, but disjointed computations for magnitude and probability. Further, we found no evidence for EV processing in PC; this second-order parameter may be computed elsewhere, perhaps using magnitude and probability information from PC. These data are consistent with an attention-based account of numeric representation, emphasizing high-value events and those that are rare, but potentially impactful.

1-E-16   Toward a Greater Moderation: Neuroeconomics-based financial-system regulation may reduce bubble-crash effects of brain risk-seeking and -avoiding networks

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Objective: Neuroimaging studies of subjects exposed to lab asset-price bubbles have yielded neural and behavioral results that were interpreted on the basis of "irrational exuberance" (Smith et al., 2014), "theory of mind" (De Martino et al., 2013), and having a "future time perspective" (Ogawa et al., 2014). However, academic scholars, financial-system regulators, and journalists often have emphasized excessive financial risk taking to explain asset-price bubbles. Clinicians report risky behaviors in association with substance-related or behavioral addictions (e.g., gambling disorder and internet gaming disorder). Therefore, a systematic literature review will focus on the neurobiology of addiction and risky behavior to develop a hypothesis about neural networks potentially involved in asset trading underlying financial-market bubbles. Methods: The review included neuroimaging studies of risky decision-making tasks (e.g., the Balloon Analog Risk Task [BART] and the Columbia Card Task [CCT]) and substance-related or behavioral addictions. Results: Healthy subjects' BART decisions were predicted by the balance of functional magnetic resonance imaging (fMRI) activations in a risk-avoiding cortical-control network and a risk-seeking network (Helfinstein et al., 2014). Resting-state fMRI studies of functional connectivity revealed that, compared to control subjects, individuals with heroin addiction (Xie et al., 2014; Zhai et al., 2015; Zou et al., 2015) or internet gaming disorder (Dong et al., 2015) show greater connectivity between regions in the reward valuation circuit (e.g., nucleus accumbens, ventromedial prefrontal cortex, and amygdala), but less connectivity in the frontoparietal cognitive-control network. Across all subjects, functional connectivity in the valuation and control networks was inversely correlated (Xie et al., 2014; Dong et al., 2015). Healthy subjects' near-infrared spectroscopy (NIRS)-recorded prefrontal cortical activity was higher in the "cold" deliberative version of the CCT compared to the "hot" affective CCT version (Holper and Murphy, 2014). Conclusions: If financial risk taking is associated with asset-price bubbles, then the above pattern of results is consistent with the hypothesis that asset trading-related lateral neocortical activity is higher during non-bubble periods of markets, so low trade-related lateral neocortical activity may be a NIRS-detectable biomarker of bubbles. Lowered

economic volatility of the "Great Moderation" may have ended with the recent global financial crisis (Rudebusch, 2010), but neuroeconomics-based financial-system regulation may become a useful tool for reducing asset-price volatility.

1-E-17   Tracing Intuition and Deliberation in Risky Decision Making for Oneself and Others

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The aim of our study is to explore the mechanism behind risky decision-making and how it interplays with intuition and cognition in the decision-making process for oneself and other individuals. Researchers unanimously agree on the importance of risky decision-making for oneself and other individuals. However, there is little agreement on the direction and significance of the differences in self-other choices under risk. For example, Chakravarty et al. (2011) and Pollmann et al. (2014) find that individuals are less risk averse when they make decisions for anonymous others. On the other hand, Eriksen and Kvaløy (2010) show the opposite result: individuals are more risk averse when making decisions for others. However, in this study decision-makers have met individuals affected by the decision beforehand. We hypothesize that the differences in findings in the literature can be attributed to different decision-making modes that are activated when making a choice. We propose that the emotions experienced at the moment of decision-making play a more significant role when individuals make decisions for themselves as they are directly affected by the outcomes compared to making decision for a random, anonymous individual. Stronger affect experienced during the decision making may activate intuitional processing, while decisions for others might activate more deliberative, cognitive processing (Jung et al., 2013). To identify causal effects of intuition and deliberation, we manipulate processing modes in an eye-tracking experiment and investigate the information search pattern in a risky choice situation for oneself and for another anonymous participant. Our findings will help better understand whether risk preferences are stable or depend on the context of the decision. Furthermore, they will show how mode of thinking affects attention and information collection pattern in risky decision making process. The results are relevant in designing policies that aim to help individuals make optimal decisions when taking risks for oneself but also for other people (e.g. in case of financial investors, managers or doctors).

2-E-18   Investigating the building blocks of naturalistic risk-taking: Risk-perception in the Balloon Analogue Risk Task

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Many neuroeconomic studies have identified a network of brain regions that responds to economic risk. The tasks used in these studies are relatively simple and allow for decomposition of cognitive constructs, but have been of limited success in predicting naturalistic risk-taking outside the laboratory. On the other hand, the Balloon Analogue Risk Task (BART) has shown to correlate with a number of naturalistic risk-taking behaviors, but its underlying cognitive constructs are not yet well understood. A number of computational models developed by Wallsten, Pleskac and Lejuez (2005) and Pleskac (2008) suggest possible cognitive components underlying behavior in the BART. In our study, we further tested the role of one component, risk-perception, in the BART, by asking people about their estimation of outcome probabilities in the task. Results suggest, that people constantly overestimate the risk in the BART, which we discuss in light of how individual differences in risk-perception influence risk-taking behavior in the task. Additionally, we investigate the assumptions of existing cognitive models in terms of risk-

perception. Finally, we test the connection between risk-perception in our task with real-life risk-taking behavior such as smoking and drinking. The findings of this study could, on the one hand, generally inform about the role of risk-perception onto real-life naturalistic behavior. On the other hand, the study suggests a way of focusing on risk-perception in neuroeconomic studies, to help understand neuronal underpinnings of risk-taking behavior that is applicable to naturalistic behavior outside the laboratory as well.

F – Intertemporal Decision-Making & Self-Control

1-F-19   Models of Discounted Utility in Intertemporal choices: Group vs. Individual Analysis

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In a typical intertemporal task, people tend to prefer smaller, but immediate rewards, to higher, but delayed ones. The derived discounted utility (DU) function is better described by a hyperbolic function than the normative, exponential function. This bias was hypothesized to be a result, at least in part, of a non-linear, compressed form, time perception. However, only group-averaged empirical data support this hypothesis. Objectives: The aim of this study was to evaluate the explanation power of the DU by the subjective time perception based on group-level analysis as compared to individual-level. Methods: Twenty-five undergraduate students (ages: 18-22; 17 women) performed an intertemporal choice task, with the independent variable being the time delay (3-36 months) and the dependent variable the amount to be paid after that delay. The dependent variable was varied dynamically and the threshold was estimated as the average of four reversals of choice. The same participants also performed a time perception task in which the independent variable was the time interval (3-36 months) and the dependent variable was the length of a line indicated by the participants. Five blocks of data were collected from each individual in the second task. Results: Best fitting of a linear, exponential and hyperbolic functions to the DU data achieved R2 of 0.85, 0.93 and 0.97, respectively. Substituting the objective time by the estimated subjective time, the respective R2 were 0.84, 0.88 and 0.91. When the same analysis is performed on individual basis, R2 was reduced for fitting before adjustment for the subjective time (average and standard deviation 0.59±0.25, 0.67±0.23, 0.70±0.21) and after the adjustment (0.42±0.15, 0.45±0.20, 0.67±0.58). Conclusions: The findings confirm results from previous studies showing that group-level averaged DU is better explained by hyperbolic functions than by linear or exponential functions. However, our analysis reveals that the hyperbolic model is weaker when applied on an individual level basis. The same pattern is evident after adjustment to a subjective time perception, with the exponential model maintaining its relatively low explanatory power in comparison to the hyperbolic model, thus not confirming the hypothesis that time perception explains part of the non-normative behavior. Overall, the findings suggest a further investigation of the decision-making processes on an individual-level analysis.

1-F-21   Reducing left dlPFC excitability with tDCS affects weighting, but not timing, of food attributes during dietary choice

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Objective: Self-control is an essential aspect of successful decision-making that allows us to maintain long-term goal while avoiding choices that may give immediate satisfaction but are ultimately inferior for our well being. Dorsolateral prefrontal cortex (dlPFC) is an important correlate of self-control in various contexts, including dietary choice. Findings from a recent study using computer mouse response

trajectory analyses during dietary choices (Sullivan et al., 2015) suggest two potentially distinct mechanisms through which dlPFC might affect food choices: dlPFC may alter 1) the magnitudes of taste and health influences, or 2) the relative times at which taste and health information are incorporated into value computations. Here, we used a combination of dlPFC-targeted tDCS and a drift diffusion model (DDM) with a time-varying drift rate to dissociate these putative mechanisms. Methods: Healthy participants (N=174) made dietary choices while undergoing anodal, cathodal, or sham tDCS over the left dlPFC. For each participant, we constructed choice pairs in which choosing the healthier option meant foregoing the tastier option. In order to validate our DDM with time-varying drift rate, we first fit this model to the data from the previous dietary choice study with computer-mouse responses (Sullivan et al., 2015) and obtained similar timing estimates. We then examined how tDCS polarity affected the changes from baseline in drift rate and relative onset times for the taste and health attributes. Results: Cathodal, but not anodal, tDCS significantly increased the relative taste weightings compared to sham (mean posterior density distribution cathodal - sham = 0.215 ± 0.106, p = 0.021). Health weightings and the relative onset times of the health attributes were not affected by tDCS. Changes in the taste and health weightings as well as the relative onset times of the health attributes also explained changes in self-control rates under tDCS (taste weighting coef. = -0.10, t = -4.14 p = 5.78e-05; health weighting coef. = 0.12, t = 3.77 p = 0.0002; health relative onset time coef. = -0.10, t = -.393, p = .0001). Conclusions: Our DDM can be used to accurately identify the relative onset times for considering health attributes during dietary choice. Inhibition of neuronal excitability in left dlPFC increased the weighting of taste evidence during dietary choice, which in turn related to reduced self-control. While the relative time at which the health attributes entered into the choice process was closely related to self-control, it is not affected by left dlPFC-targeted tDCS.

1-F-22   Attention to a common healthy consequence in food gambles diminishes dietary self-control

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Despite extensive research on the mechanisms of dietary self-control, it is not well understood how these mechanisms can be altered by contextual cues to improve choice. One crucial contextual element of food choices is the identity of other items in the choice set. Wilcox et al. (2009) find that the presence of a healthy option can paradoxically result in more indulgent choices. In this experiment, we examined whether the presence of a common healthy consequence in food gambles leads to more indulgent choices, and use eye tracking to better understand the mechanisms behind this phenomenon. On each trial, participants (N=60) chose between two gambles, each with an equal chance of receiving one of two foods. In two thirds of the trials, both gambles had a common consequence that was healthy but less tasty. In one gamble option, this common consequence was paired with another healthy food. If a participant selected that gamble, s/he was certain to receive a healthy item. The other gamble presented a choice between the healthy common consequence and a more indulgent item. If subjects selected this gamble, they had an equal chance of receiving either a healthy but less tasty food, or an unhealthy but tasty food. In the remainder of the trials, the common consequence was a tastier less healthy food, and these trials served as a control. Eye position data were recorded throughout the experiment. Participants were primed for eating healthier, or for eating high taste foods, by reading a brief text before the task began. Despite being irrelevant to the choice, the common food item consists of 18.2% of total food dwell time on average. Moreover, the mere presence of a healthy common consequence dramatically reduces the percentage of healthy choices, relative to trials in which the

common consequence was a tastier, less healthy item (T=-7.14, p=1x10-10). This effect was immune to the influence of priming (F=0.57, p=.45). Total gaze time on the irrelevant common item was correlated with the decrease in self-control ability from common tasty consequence to common health consequence trials (R2=.09, p=.036). Because the common consequence is irrelevant, it should not be attended to after an initial gaze to discover its identity. However, our results suggest that the presence of a common healthy consequence give participants license to choose the gamble with a "risk" of receiving an unhealthy treat. Susceptibility to this bias may be driven by excess attention to the common consequence during choice. Wilcox, K. et al. (2009). "Vicarious Goal Fulfillment: When the Mere Presence of a Healthy Option Leads to an Ironically Indulgent Decision." J Consum Res.

G – Computational Modeling

1-G-23 **Modeling choices and response times during reinforcement learning**

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Many decisions we make every day are between options whose value we can only infer through experience (e.g., deciding between two new restaurants in town), and whose value might change with time (e.g., declining quality of a restaurant we already know). These decisions are usually studied in the lab within the feedback paradigm. In this paradigm, participants make repeated, consequential choices between the options. Reinforcement-learning (RL) models are used to describe and explain the updating of beliefs about the options' values. RL models typically do not take response times (RTs) into account. However, RTs can provide a better understanding of the mechanisms underlying the decision process. Sequential sampling models (SSMs) have been very successful in predicting both choices and RTs in various domains. However, very few attempts have been made to extend these models to the feedback paradigm (e.g., Frank et al., 2015, J Neurosci). In our experiment, 32 participants completed three blocks of 80 trials in which they chose between options whose payoff was normally distributed and with different means. As expected, participants became faster and more accurate in choosing the options with higher means throughout the trials. This effect was stronger when the difference between the means of the options was larger. Moreover, participants were faster but not more accurate when the means of the options were higher. We then compared the quantitative and qualitative fits of different models. The best model assumes that people update their beliefs according to a simple RL rule, and that the choices emerge from an accumulation-to-bounds process. The speed of accumulation depends not only on the value difference between the options but also on how certain the decision maker is about these values. Finally, the bounds are modulated by the overall mean of the options (decisions get faster but not necessarily more accurate when choosing between overall better options). Our results go in the direction of building a better learning and decision model, that can be used to make quantitative and qualitative behavioral and, in the future, neural predictions. We showed how inspecting RTs can be important as they show patterns that are not visible in choice data alone, and therefore help us to give a more accurate account of the underlying cognitive processes.

1-G-24 **Testing the selective integration model with the dot-probe technique**

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Objective: While normative models of choice assume that values are constructed in a context-independent manner, actual choice behavior violates this assumption, as indicated by intransitive preferences, contextual preference reversals and risk biases. These puzzling phenomena were recently

accounted in a neuro-computational selective integration model, according to which, attention is directed towards information congruent with the observer's goals, whereas incongruent information is discarded or underweighted. The aim of our study was to explicitly test this attentional allocation mechanism, using the dot-probe paradigm. Methods: 2 experiments are reported (N1=15, N2=20), in both participants were presented with trials in which rapid sequences of pairs of numerical values, corresponding to two alternatives (such as stock returns or rewards of slot machines) are presented. In half of the trials, a small red dot briefly appeared in the center of one of the numbers. At the end of each trial, participants were asked to first indicate which one of the sequences had higher mean (experiment 1), or from which they would prefer to receive an extra-sample (experiment 2). Second, participants were asked whether they have seen the dot or not (experiments 1&2). We manipulated the location of the dot (whether the dot appeared in the pair higher or lower number) and the means and variances of the sequences. Results: We show that dots located within the larger of two simultaneously presented numbers have higher detection-rate, compared to dots located within the smaller number (experiments 1&2). Additionally, we replicated the pro-variance bias: participants favor the riskier option associated with broader distributions. Crucially, we showed that the dot-probe bias effect is correlated with the risk-seeking bias, as predicted by the selective integration model. Conclusions: The results provide support for a process model of risk biases in choice, according to such biases are the result of attentional mechanism that prioritizes the integration of values congruent with the observer's goal.

1-G-25   Parsimony and prediction errors: Ventral striatal PEs are not uniquely explained by parameterized learning models

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Computational models are powerful tools to investigate cognition, yielding specific and falsifiable predictions about behavior on the basis of theorized latent cognitive processes. They may provide a bridge linking multiple levels of inquiry- from the behavior, the cognitive process, to the neural substrates implementing those processes. In the context of fMRI this can be accomplished by regressing the predictions of a model fit from the behavioral data against BOLD responses to identify brain regions that may be carrying out those computations. However, as a correlational approach, identifying a region consistent with a model-defined process is not strong evidence that the brain region carries out that process. Nevertheless, in studies of model-based fMRI it is uncommon practice to include models that do not rely on the assumptions of the primary computational model as a basis of comparison. This study investigates whether striatal responses at outcome in an instrumental learning task (the IGT) are better explained by model-derived prediction errors (PE) or whether the same striatal responses can be captured by regressors derived from an analogous, but non-model-based process that does not rely on the assumptions of any learning model. Subjects' behavioral data was fit using the Prospect Valence Delta-Learning model (Ahn, et al., 2014) of the IGT. Specifically, the parameters were estimated by hierarchical Bayesian estimation procedures. Trial-by-trial regressors corresponding to expected value (EV) and PE for the decision and outcome phases, respectively, were computed for each subject on the basis of mean parameter estimates from their individual-level posteriors. A second set of regressors analogous to EV and PE were computed iteratively, but algebraically from subjects' choice and outcome histories. The process is fundamentally not RL-algorithmic as EV in this context is not a function of "PE", nor is it subject to discounting as with a learning model. Model-derived PE identified ventral striatum and model-derived EV identified subgenual PFC, consistent with prior studies. However, the non-model

based process identified same set of regions. Magnitude and valence of the outcome were included in a secondary set of models. Striatal variability at outcome was better explained by these variables. This study does not undermine the abundant evidence for dopaminergic PE in general. The possibility remains that the quality of the model fit or model-task interactions impact these results. Nevertheless, they strongly demonstrate the importance of ruling out potentially more parsimonious explanations for neural processes identified via computational models in fMRI.

H – Game Theory & Strategic Interactions

1-H-26   How oxytocin fine-tunes decision making in social dilemmas: cooperate as long as it pays off, but aggress only when you think you can win! An fMRI study.

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The neuropeptide oxytocin (OT) gained attention in neuroeconomics as experiments with intranasal administration show that it can boost trust, reduce anxiety, and increase the relevance of salient social cues. However, more often, OT has a moderating effect, with pro- or antisocial consequences depending on context. Here we investigate how context matters, and what the effects of OT are when multiple pieces of information have to be integrated at once. Key social decisions require an evaluation of (1) how context incentivizes one behavior over another, and (2) how contextual cues are informative with regard to the outcome of that behavior (i.e., whether the desired behavior is safe or dangerous). Objectives. We set up an experiment to test if OT can improve the accuracy of complex decision-making in strategic interactions by facilitating the integration of incentives and social cues. We also test if this occurs through OT's modulatory effects on the nucleus accumbens and amygdala, two regions of the brain that are involved in generating incentive motivation and in evaluating the valence of social stimuli respectively. Methods. Participants (N = 30) played two economic games under the MRI scanner after they received 24 IU of intranasal OT or placebo (following a double blind, within-subject design). The games vary in the incentives they provide: the assurance game (AG) simulates a win-win environment and incentivizes cooperation, while the chicken game (CG) simulates a win-lose environment and incentivizes aggression. Pictures of angry or neutral faces were displayed on the screen alongside the game matrices in order to suggest a threatening or safe decision environment. Results. In the AG, where cooperation is the most desirable option for both parties, facial cues are not relevant, and OT facilitates cooperation for risk averse individuals. Here OT activates the nucleus accumbens significantly more than in the CG. In the CG, where aggression is the most desirable option but fatal if the partner also aggresses, facial cues are highly relevant. Here OT significantly downregulates the amygdala, while behaviorally, it steers decisions in accordance with the valence of the cue: aggress when cues are neutral; retreat otherwise. Conclusions. Taken together these results are compatible with the theory that OT facilitates heuristic decision making by modulating brain regions in the mesolimbic dopaminergic system. Through its combined effect on the nucleus accumbens and amygdala, cooperative or aggressive decisions are selected in function of the best match between incentives and social cues present in the decision context, thereby improving ecological accuracy.

1-H-27   What Drives the Theory of Mind Network? Disentangling the Effects of Social Context from the Prediction Problem.

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Objective: It is well established that the so-called "Theory of mind network" is more active when

humans compete in social settings compared to non-social settings. The theory posits that activity in the mentalizing network, and especially in rTPJ is driven by the social context. However, this descriptive account leaves a key question unanswered: What makes social special? We suggest that the effect of social context may have been confounded with the type of prediction problem that the brain expects to encounter. Methods: 64 healthy volunteers participated in the experiment in the fMRI scanner. Thirty-two participants played a game of hide and seek in a social context while the rest played the game in a non-social context - only the framing differed between both conditions. Participants played against two distinct opponents/decks of card. A learner algorithm, that reacts to the actions of the players, and a sequencer algorithm that tends to produce tuples. Both algorithms were formally matched in terms of objective difficulty. Our experiments can be summarized as a 2x2 design, with framing as between-subject condition and algorithm as blocked within-subject factor. Results: As expected, behavioral results indicate that the Social context exerted a strong facilitation effect when competing against the Learner algorithm, suggesting that players expect their opponents to learn and react to how they play in a social setting. Using "Theory of Mind" as search term on Neurosynth, we created independent ROIs and made use of a simple, model-free GLM. We extracted betas for the choice Epoch and the feedback Epoch across framings and algorithms. Activity in key regions of the theory of mind network were found to be significantly higher, across the board for the choice and feedback period, when playing against the Learner algorithm with the Social context having no noticeable effect. These results hold while controlling for the post-experimental beliefs of our participants - and while we do find a significant effect of Social beliefs in some regions; the evidence overwhelmingly favors the prediction problem hypothesis over the social context hypothesis. Conclusions: Our results suggest that what makes social special in a competitive setting is the expectation that the environment will react in a sophisticated way to the player's actions. On the neural level, the driver of activity in the "Theory of Mind"network is not the fact per say that one is playing against a fellow human, but the nature of the prediction problem that the brain is trying to solve - and we suggest that the key characteristic that sets these problems apart and recruits regions such as rTPJ is the learning of the opponent.

1-H-28   Visual search patterns predict the level of sophistication in interactive games
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Objective: Recent eye-tracking studies of game playing suggest the existence of individually heterogeneous-but-stable patterns of visual information acquisition based on subjective levels of strategic sophistication (Polonio et al. 2015). However little is known about the link between basic attentional indices and the level of sophistication in games. Our objective is to directly investigate whether it is possible to predict players' behavior in games by analyzing their attentional patterns in a basic attentional task. Methods: We recorded eye-movements of 61 participants while performing two different tasks: 1) a visual search task consisting of 120 trials in which participants have to detect, as fast as possible, a target among several distractors, and an interactive task consisting of 48 one-shot games in which either, neither, or only one of the players involved in the interaction had a dominant strategy. We then grouped participants according to the visual search patterns they made during the visual search task and compare the level of strategic sophistication they adopted in these games. Results: In the visual-search task, the ability to be more flexible in the way attention was allocated lead to higher accuracy and optimality. Interestingly, this ability predicted the level of sophistication adopted in interactive game playing. More specifically, we found a group of participants whose visual-scan path in the visual-search task was driven by the contingent distribution of elements. This indicates that

participants were able to adapt their analysis to the specific characteristics of the stimulus. In games, these participants exhibited a more sophisticated visual-analysis that allowed them to choose more optimally. In particular, participants acquired more frequently all the relevant information following a consistent and dynamic pattern of information acquisition that leads to the equilibrium. Participants who exhibited a scan-path that was independent from the actual distribution of elements in the visual-search task deviated more frequently from this visual information acquisition pattern during the game interaction. Conclusions: We found that simple attentional indices of strategic flexibility predict optimality in a visual search task and, more importantly, the ability to best respond to the expected action of the opponent in games. These findings establish a link between basic attentional mechanisms and the level of sophistication in interactive games.

I – Learning & Memory

1-I-29   Dynamic computation of hierarchical prediction errors during sequence learning

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Sequence learning is the ability to learn about the temporal patterns of environmental stimuli, and is a crucial ability for much of human cognition and behavior. Many behavioral and neuroscience studies have shown that humans attempt to identify patterns in order to predict future events, even when these patterns do not provide information about future outcomes (1). Neuroimaging research on sequence learning has proceeded largely independently of the research on computational reinforcement learning, because the focus is primarily on learning statistical dependencies of stimulus sequences rather than on optimizing reward-based performance through learning. Here we investigated whether and to what extend mechanisms of reinforcement learning are also employed in statistical sequence learning. Standard reinforcement learning model (2) postulates that average rewards are estimated for all available actions and that action selection is biased towards the most rewarding option. It cannot explain, however, how subjects can learn in situations where the average rewards for all the options are equal but the reward received is conditioned on a specific sequence of events. We hypothesized that hierarchical prediction errors are computed to learn the conditional correlations. To test this hypothesis, we developed a Markov decision task where we precisely control the temporal dependencies by first- and second-order transition probabilities. 25 participants performed the task while being scanned with fMRI. We analyzed the fMRI data with higher-order reinforcement learning models and compared the model-based results with the results obtained with other computational strategies, e.g., Bayesian sequence learning (3) and the win-stay-loss-shift strategy (4). We found lower-order prediction errors in the ventral striatum and higher-order prediction errors in the prefrontal and parietal cortices. Our results suggest that the neurobiological mechanism of reinforcement learning is dynamically involved in the processing of temporal dependencies and that the human brain implements reinforcement-learning mechanism to estimate higher-order probabilities in the same manner as estimating the zero-order average rewards. 1. S. A. Huettel, P. B. Mack, G. Mccarthy, Nat. Neurosci. 5, 485-490 (2002). 2. R. S. Sutton, A. G. Barto, Reinforcement Learning (MIT Press, Cambridge, MA, 1998). 3. D. Ostwald et al., Neuroimage. 62, 177-188 (2012). 4. D. A. Worthy, W. Todd Maddox, J. Math. Psychol. 59, 41-49 (2014).

1-I-30   Neural evidence for non-reward prediction errors in the auditory cortex

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Predictive-coding models suggest that the brain uses internal, predictive models of the external world to anticipate forthcoming stimuli and minimize encoding of redundant information. In this framework, prediction-error signals are the main teaching signal used to update internal models. A wealth of evidence indicates that reward prediction-error signals are central to predictive learning in reward systems, but less is known about the exact nature of the neural computations underlying predictive learning in sensory systems. Here, we adapted an axiomatic approach derived from neuroeconomics to formally test whether sensory systems encode (non-reward) sensory prediction errors. Participants completed a probabilistic speech discrimination task that explicitly manipulated expectations for hearing speech or non-speech vocal sounds on each trial (probabilities of speech vs. non-speech: 0, 0.25, 0.5, 0.75, 1). Functional magnetic resonance imaging (fMRI) was acquired while participants performed the task to determine whether neural signals at the presentation of speech or non-speech auditory stimuli conformed to sensory prediction errors. Behaviorally, participants discriminated the stimuli more accurately and faster on trials that presented more certain information (0/1>0.25/0.75>0.5), indicating that they incorporated probabilistic information into the decision process. Post-task pleasantness ratings, validated using an incentive-compatible two-alternative forced choice task where listening to a sound clip for 2 minutes after the task was determined by one randomly selected choice, indicated that speech and non-speech stimuli were equally pleasant. This confirmed that stimulus category was independent of reward value. Analysis of fMRI data revealed that blood-oxygen-level-dependent signals in voice-selective regions of the temporal cortex tracked non-reward, signed prediction errors. These signals did not represent stimulus-specific adaptation given that prediction errors depended on the explicit probabilistic cues and not on trial history. Furthermore, these signals were weighted by the precision (inverse of binomial variance) associated with the known probabilistic cues, suggesting that more uncertain outcomes are associated with more influential prediction-error signals (greater update rate). These findings support the notion that prediction-error signals are a ubiquitous teaching signal used across brain systems outside the reward system.

1-I-31 Observational Learning and Intelligence

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Objective: In a behavioral experiment we study how people learn from observing others. We measure intelligence of the observer and the observed and explore what information is transferred to the observer and how intelligence modulates the mechanism of observational learning. Methods: Subjects make choices in a 2-armed bandit problem. They observe two symbols on the screen and choose between them in multiple trials. The environment is non-stationary: the probabilities of getting a reward from each option follow a random walk throughout the whole experiment. Sometimes, before making their choice, subjects also observe the choice of one other subject (but not the outcome that the other has obtained). Subjects are aware that the other chooses in the same environment as they do, thus the information about other's choice is valuable. Before this learning task subjects take 30 items Advanced Raven test and are informed about their score. In one treatment they are also informed about the distribution of Raven scores from previous experiment, but not about the Raven score of the subject they observe. In another treatment, subjects are provided the information about both the distribution of the Raven scores and the Raven score of the subject they observe. Results: We find that high Raven score subjects learn very differently from low Raven score subjects. In particular, high Raven score subjects use many sources of information when observing the other: they imitate the other more if the value of imitation (average payoff from choosing the same action as the other) is high; they imitate less

if the number of times that the other switched to different action is high; and they imitate less if their average past payoff is high. This indicates that high Raven subjects use sophisticated learning techniques. Low Raven subjects use only simple value of imitation information and nothing else. We find that high Raven subjects are more optimal and earn more money than the low Raven subjects. Moreover, they are much better at recognizing if the other subject is worth imitating. Even in the treatment where information about the Raven score of the other is not revealed, high Raven subjects are able to recognize more optimal other just from the choices that the other makes. Conclusions: We find that intelligence has significant influence on how people learn from observing others. Subjects with low intelligence use simple learning techniques and tend to overestimate the information about the intelligence of the observed. High intelligence subjects learn from the choices of the observed and manage to extract information about the environment from their observations.

J – Valuation & Value Systems

1-J-32   Managing a zoo with the medial prefrontal cortex

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Objective: Standard models of value-based choice assume that the brain integrates potentially incommensurable outcomes into a single common value function. However, in natural settings, animals must often independently maximise multiple distinct assets. For example, a thirsty animal will value a liquid reward over a food reward, whereas the reverse is true for a hungry animal. Thus, in order to choose optimally between two distinct assets, animals must integrate the respective values on offer in the context of their internal resource levels. However, little is known about how the brain keeps track of resource levels associated with a given asset, and how these contextual representations guide model-based decisions. Methods: Human participants performed a task that involved accumulating two assets (lions and elephants in a virtual zoo) in the fMRI scanner. Each trial involved an offer of a variable number of lions and elephants. Participants received trial-wise rewards that related to the category with the minimum number of accumulated animals in each category (i.e. they tried to maximise the minimum of either asset). Periodically, the accumulated resources were reset to zero, decoupling asset accumulation from the passage of time. We asked how neural structures previously implicated in representing economic value responded to the magnitude of each offer, and the relative value of the chosen and unchosen option. However, the paradigm also allowed us to ask how these representations were modulated on a trial-by-trial level by ongoing resource levels. Results: Although on average participants favored the choice with more animals on offer (offer-based choices; i.e. choose 4 elephants over 2 lions) choices were strongly modulated by ongoing resource levels for either asset (resource-based choices; i.e. lions might be preferred if accumulated lions in the zoo were low). In the neural domain, we observed a dissociation between offer and resource-based value encoding: while the ventral striatum encoded the value of the chosen relative to unchosen option, BOLD signals in the vmPFC scaled with the increase in resource value for the current minimum asset, and encoded the absolute level of resources as they accumulated over time. By contrast, more dorsal regions of the medial prefrontal cortex, peaking in the rostral anterior cingulate cortex (ACC) coded for the difference in the two cumulative resources. Conclusion: One interpretation of these data is that the vmPFC encodes values in the context of overall goals, while also updating progress towards this goal, whereas ACC facilitates changes in context-based decision strategy.

1-J-33   **Observational Learning Increases Goal-Directed Control**

Brenton Keller[1], Giorgio Coricelli[1]

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Human behavior is mediated through two systems, one that is goal-directed and the other habitual. Individuals with compulsive disorders have been shown to have reduced goal-directed control. Studies examining goal-directed versus habitual control have mostly discovered methods in which to decrease goal-directed behavior, in favor of habitual behavior. In the present study, we investigated observational learning as a tool for increasing goal-directed behavior. Subjects underwent three rounds of testing. In the first round, subjects performed a two-stage task used to differentiate model-free and model-based behavior. In the second round, subjects observed and predicted another individual playing the same two-stage task from the first round. Half of the subjects observed and predicted a model-based player, while the other half of the subjects observed and predicted a model-free player. In the third round, the subjects replayed the two-stage task from the first round. Subjects who used a model-based strategy in the first round were significantly better at predicting a model-based player, compared to a subject who used a model-free strategy in the first round. There was no significant difference between the prediction accuracy of model-based subjects and model-free subjects when predicting a model-free other. Model fitting results show that the lack of prediction accuracy differences between model-free and model-based subjects is explained by model-based subjects changing their choice strategy to match the model-free player. Furthermore, model-free subjects who predicted a model-based player showed a significant increase in model-based behavior in the third round. This increase of model-based behavior was not present in model-free subjects who predicted a model-free player, nor in a supplemental study where model-free subjects played the two-stage for all three rounds. These results suggest that observational learning and behavioral prediction may be used as a behavioral therapy to regain goal-directed control.

1-J-34   **A framework to reveal brain functional phenotypes: the case of the brain valuations system(s)**

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Intro: Most neuroimaging studies rely on the fundamental assumptions that the neuronal implementation of a cognitive variable is both task- and subject-invariant. In this work, we challenge these assumptions by analyzing a series of neuroimaging datasets investigating "value" representation. Methods: We gathered three neuroimaging datasets, collected while three different cohort of participants performed three variants of a value-based decision-making task: i.e. judging the pleasantness/desirability of different types of items. As previously reported, we found that values are consistently represented in a limbic network, with the VMPFC as a core node, across the 3 experiments. We parcelized individual activation maps in 45 ROI, based on macroscopic anatomical architectonic atlas, and fed it to one of the most popular clustering methods - Gaussian mixture models (GMM) - to uncover the inter-individual variability structure in value-activations. Our unsupervised machine-learning technique coupled with a model-comparison approach identified 3 discrete clusters - later referred to as "phenotypes" - regrouping respectively roughly 50%, 25%, and 25% of subjects, evenly distributed across the tasks, with no significant differences in demographic or behavioral summary statistics. In order to dissociate task- and subject- variant and invariant value activations, we arranged individual whole-brain value activation maps in a 2*3 factorial model, using "phenotypes" and "tasks" as 2 factors with 3 levels. We assessed factor-invariance using conjunction tests across the levels of our factors, and factor-dependence by testing for the factors main-effects. Results: We formally

demonstrate that "values" are represented in the vmPFC in a task- and phenotype-invariant fashion. Critically, our neuroimaging ANOVA also reveals that value-related activity in another large network (dACC, PCC, and AI) discriminates our 3 clusters of subjects (phenotypes). We then show that the two networks contribute a unique share of the final behavioral "value" variance, and that those contributions are fundamentally different across the distinct phenotypes. Discussion: Our results suggest that there exists a limited set of different brain functional phenotypes in the population, which in turn output the same cognitive variable (e.g. value) across task-variants. This may challenge the traditional view where inter-individual variability in activations is mostly considered as noise, and averaged-out in random effect analyses. The identification and investigation of those neural phenotypes may prove critical to refine our understanding of mental computations and brain functions.

1-J-35   Brain mediators of Marketing Placebo Effects on Experienced Pleasantness
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Previous research in consumer psychology suggest that expectancies about product quality induced by marketing actions such as pricing or branding alter consumption utility computations. Such marketing placebo effects (MPE) were also shown to alter experienced pleasantness encoding in the brain. However, the putative neural mechanisms linking marketing actions to experienced pleasantness are unknown. We reasoned that brain regions implementing MPE should satisfy three criteria: (1) activate in response to price tag, (2) predict experienced pleasantness and (3) mediate the effect of price tag on experienced pleasantness. To test this framework we scanned 30 participants (mean age: 30.4±1.8 years) using functional magnetic resonance imaging while they tasted identical wines believed to be sold at different prices (3, 6, 18 euros). Unbeknownst to the participants the retail price of all wines was identical (12 euros). In some trials, participants received the wines for free, in other trials participants had to pay for the samples that they tasted. In line with previous work from our group, high prices increased experienced pleasantness ratings ($F(2,179)=42.65$, $p<0.001$). There was no main effect of the payment condition and also no interaction between price tag and payment condition. Standard univariate analyses of brain imaging data further replicated previous findings on the neural level. Brain regions involving the medial and ventral orbitofrontal cortex and ventral striatum activated stronger in response to the degustation of wines sold at high prices compared to low price wines. Whole brain mediation analysis, testing for brain mediators of the effect of price tags on experienced pleasantness ratings by jointly controlling for effects of both price tag on brain responses and brain responses on experienced pleasantness, revealed that the ventral striatum, the right fronto-polar cortex and the ventromedial prefrontal cortex satisfied the three hypothesized criteria for a neural substrate formally linking marketing placebos to experienced pleasantness. Our results are in line with the literature replicating MPEs on a neural and behavioral level. Crucially, we provide novel evidence for a neural substrate linking marketing placebos to experienced pleasantness, which was located in brain regions known to be part of the brain?s valuation system. This finding parallels neuroscience research on placebo effects in pain, and offers a new perspective on the appetitive side of placebo effects in healthy subjects.

1-J-36   Finding it hard to change your mind after one bad experience? You might be too Bayesian.
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When making decisions in a social environment, it is important to update impressions based on experiences in order to accurately represent our collaborators/opponents. However, early negative information tends to have a greater impact (Fiske, 1980; Rozin, 2001), forming evaluations that resist later updating (Hogarth & Einhorn, 1992). Why does negative information have such prominence? Is this wholly irrational, or can it be traced to normative inference? We hypothesized that (1) the inherent low frequency (Fiske, 1980) and (2) greater variance (Unkelbach et al., 2008) of negative events may lead to inference of unique latent cause for such events. That is, due to the fact that negative events are generally sparse, we might infer that these events are relatively 'unique', produced by latent causes with small consequential regions (Shepard, 1987). This tendency to separate negative events to small latent causes, while grouping positive events in large latent causes that explain multiple events, can cause negative-positive asymmetry in learning even for fully rational agents. Here, we test this hypothesis using simulations with a Chinese Restaurant Process prior. We generated stimuli by sampling from two non-overlapping uniform distributions with unequal sample size (Study 1) or unequal variance (Study 2). The data were then used to estimate the posterior probability of consequential regions. A Particle Filter was used to approximate Bayesian likelihood. The posterior distribution of consequential regions for negatively-valenced stimuli from the generative model where these were rare (Study 1) or had greater variance (Study 2) showed higher entropy than did the posterior for positively-valenced stimuli (mean difference = .94; p < .001). This indicates that the negative stimuli were assigned to more latent causes with smaller consequential regions than the positive stimuli. These results suggest two possible mechanisms for the higher impact of negative events in impression formation and updating. In real-world scenarios negative events may be both rare and more variable, compounding these two separate effects.

K – Choice & Choice Systems

1-K-37   Evidence for Revealed Similarity in Value-based Choice Behavior

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Objective: Similarity, or the ease of comparison between options has recently been posited to be an influential factor in understanding context-dependent choice. Here, we attempt to recover data-driven estimates of similarity between goods using choice data alone. We also investigate whether probabilistic choice between pairs and triplets of goods are affected by the magnitude of these pair-specific parameters (as well as by the subjective valuations of individual goods). Methods: The experimental protocol consisted of an online experiment with three sections (N = 48). The first block consisted of "bidding" trials, where subjects were asked to declare a hypothetical willingness-to-pay for 30 different snack items, three times each in a randomized order. In the second block, subjects chose between all pairwise combinations of the same 30 snack items, also in a random order. Lastly, subjects completed a trinary choice task where they were required to choose between triplets of snack foods. The triplets were constructed a priori using eight pairs of goods. These pairs were assigned to a further third option in order to produce sets of three options. The third item in each set was selected from a subset of goods identified a priori to span a range of similarity values. Results: Average choice probabilities increased systematically with the hypothetical valuations provided in the first block. Both reaction times (RT) and choices are well-fitted by a drift-diffusion model of stochastic choice. Critically, we find evidence for pair-specific similarity parameters estimated using maximum likelihood over the pooled data. The values of these parameters are negatively correlated with average RT (r = -0.41 ,p < 0.05) in the binary choice

block while also being positive correlated with value correlations across subjects (r = 0.30, p < 0.05). In the trinary choice condition, logistic regression performed on choice reveals that choice of the highest valued good is significantly affected by both elicited value (as measured in the first block) and similarity parameters (as estimated in the second block). In contrast, the probability of observing a choice belonging to the pair of goods with the greatest similarity parameter was affected only by the similarity parameters (and not value). Conclusions: These preliminary findings suggest that the speed and accuracy of choice is significantly affected by latent pair-specific properties, as well as by distances in subjective valuation. We aim to supplement the current set of results with eye-tracking data in order to further characterize the extent to which these factors influence choice behavior.

1-K-38   **Modulation of motor cortex excitability during third-party punishment: a TMS study**

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The aim of this work is to shed light on the unexplored relationship between brain networks and punishing behaviour. We seeked to understand whether neutral third parties react to unfairness because they feel the same reaction of victims. In other words, we aimed to detect whether empathy modulates third parties' choices. In our study, we focused on the "mirror neurons system" (MNS), because it is activated both when a person performs an action and when the same person observes others performing it. MNS is involved in different processes: in understanding the intentions of others, in response to the experience of empathy and it is even sensible to fairness and economic status quo. This study is divided into three experiments in which we focused on the motor cortex activity. We investigated whether: 1) it is modulated in the victims of an unfair dictator (Study 1); 2) it is modulated in a third party that observes the victims (Study 2); 3) it is modulated in a third party that observes the victims and can punish the unfair dictator (Study 3). Healthy participants completed a Share Game (SG), which involved active players ("A", the dictator) and a passive receiver ("B"). In Study 1, B was the experimental subject, whereas in the other two studies the experimental subject was a third party. "A" had to decide how to share a gain or a loss of 50 tokens with "B", by choosing one out of six options, whereby three are gains and three are losses (40/10, 25/25, 10/40 and -40/-10, -25/-25 a-10/-40, where the first and the second number indicate "B"'s and "A"'s share of the tokens, respectively). "A" communicated to "B" the chosen option by showing a video clip where an actor grasped one out of six metal cylinders with the chosen allocation displayed on it. While the experimental subject watched the video, a TMS pulse was delivered to the his/her motor cortex and a motor evoked potential (MEP), a measure of the excitability of cortical spinal tract, was recorded from the FDI muscle. Results of Study 1 showed higher MEPs in correspondence to the individual's maximum loss (-40/-10) and to the individual's minimum gains (10/40, 25/25). Results of Study 2 showed higher MEPs when the third party observes the victims when they receive a maximum loss (-40/-10) and the minimum gain (10/40). Preliminary data of Study 3 show a similar pattern of MEP modulation as study 1. The results of our three experiments support the hypothesis that the reaction to unfairness produces a similar modulation of MNS between the victims and the third party only if the third party is allowed punish the dictator. These results underline the importance of empathy in punishment behaviour.

1-K-39   **Causal neural networks underlying social norm compliance**

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Introduction: Prominent theories propose that norm-compliant social behavior is governed by dedicated, specifically-evolved neural mechanisms. Consistent with these proposals, fMRI studies have identified a neural network activated during norm-compliant behavior (Spitzer M et al., Neuron, 2007) and a transcranial direct current stimulation (tDCS) study has demonstrated that right lateral prefrontal cortex (LPFC) is causally relevant for both sanction-induced and voluntary norm compliance (Ruff CC et al., Science, 2013). Here we use the online combination of tDCS with fMRI to identify the neural mechanisms by which right LPFC stimulation can affect norm compliance. Methods: Seventy-six participants received either anodal, cathodal, or sham tDCS over right LPFC inside the MR scanner. At the beginning of each trial, player A (inside the scanner) proposed a division of 100 monetary units (MUs) between himself and player B. Both A and B also received 25 MUs extra. In the no-punishment condition, the transfer took place immediately, whereas in the punishment condition, player B could spend a part of the extra 25 MUs to punish player A: Every MU spent by player B for punishment led to a reduction of player A's gain by 5 MUs. Results: Similar to Ruff et al., anodal tDCS increased and cathodal tDCS decreased the sanction-induced transfer difference. The decreased sanction-induced norm compliance due to cathodal tDCS was accompanied by decreased activity during the punishment condition in anterior cingulate cortex, left DLPFC, bilateral IPL, cuneus/precuneus cortexes. Conversely, the increased sanction-induced transfer difference due to anodal tDCS was reflected in increased activity during the punishment condition in the amygdala. Psychophysiological interactions analysis showed that anodal tDCS during punishment threats increased connectivity between the stimulated LPFC and orbitofrontal cortex (OFC). Conclusions: Cathodal stimulation affected brain regions within a central executive network, consistent with the view that stimulation may have modulated strategic thinking about the consequences of the punishment threats. In contrast, anodal stimulation enhanced neural sensitivity to punishment threats in the amygdala and triggered stronger punishment-related connectivity between the stimulated LPFC and the OFC, suggesting that the tDCS may have increased affective responses to punishment threats. Taken together, our findings show that the stimulated LPFC region may control social norm compliance by dynamic modulation of brain regions involved in affective and strategic responses to sanction threats.

1-K-40 Same, same but different? Evidence accumulation across moral and non-moral domains

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Objective: Several studies have indicated that diffusion based evidence accumulation models can account for choices not only for simple economic decisions, but also in social and moral domains. However, these studies have not investigated how single participant's choices can be characterized between tasks. Here we aimed to investigate decision making across a series of similar tasks in different choice domains. Methods: 60 undergraduate Lund University students participated in a multi-part study. First participants rated 60 snack food items, 30 charities and 46 positive moral action descriptions. Ratings were made on scales from -10 to +10 based on how much participants would like to eat each snack/ donate to each charity/ praise each action. Following this, participants made 100 binary choices between pairs of items within each category. Items were randomly paired, but constrained to be positively rated and with a maximal 7 point rating difference. Participants had free response times and their gaze was concurrently recorded during choices. One of the snack and charity choice trials were selected at the end of the experiment, and participants received the snack chosen on that trial to eat and the experimenters donated SEK150 to the chosen charity. Results: We found that participants in all

three tasks were highly sensitive to the underlying valuation differences, producing highly similar choice curves and, linearly shifted, response time profiles. Economic decisions were fastest and most accurate, while moral decisions shortest and least accurate. Computational modeling, in the attentional-DDM framework, indicated that error rates for derive from a combination of increased decision barriers and greater difficulty to sample evidence (lower drift rates for similar value differences). The effects of visual fixation patterns on drift were largest for economic decisions and smallest for moral decisions. Conclusions: We asked participants to make binary choices between previously valued alternatives stemming from economic, social and moral task domains. Our results suggest that the same computational process captured by an attentional-DDM can explain the patterns of choice and response times in all tasks. Available evidence, captured by drift, varied with increasing abstractness of choices, as did reliance on visual fixations.

1-K-41 Neural mechanisms of control aversion during social decision making
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When others try to control our decisions, many of us will feel the urge to counteract and thereby reestablish our valued free choice. This control aversion can lead to suboptimal decision making, e.g. opposing laws or health policies, and its antecedents and consequences have been studied extensively. The underlying neural mechanism of how control aversion is integrated into decision making in social interactions, however, remains poorly understood. To close this gap we combined a social decision making task with functional magnetic resonance imaging in a sample of healthy adults. While being scanned subjects allocated money to themselves and varying, anonymous interaction partners. Critically, their interaction partners either let them choose freely (Free condition) or requested a minimum amount to be returned, thereby controlling the subjects' choice options (Control condition). After each decision, subjects rated their feeling of being controlled and negative affects on pictorial assessment scales. The amount to which subjects returned less in the Control than in the Free condition measured individual control aversion. The results show that in the Control compared with the Free condition, subjects report feeling more controlled and return smaller amounts. Their behavioral control aversion also correlates positively with self-reported negative affects. A whole-brain analysis reveals that control over the subjects' choice by the interaction partner is signaled in the temporoparietal junction (TPJ), a brain area that contributes to decision making when a social (or nonsocial) context is relevant for current behavior. Moreover, we find that individual control aversion is associated with specific changes of neural connectivity between the right TPJ and an area in the dorsolateral prefrontal cortex (dlPFC) that has been associated with context-dependent value-based decisions. Taken together, our results suggest that control aversion is associated with the integration of relevant social information into context-dependent decision making.

1-K-42 Contributions of neural adaptation to value-based and perceptual choice
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Despite the prevalent use of two-alternative choice paradigms to study different types of decision making, real-life decisions often involve selection among a set of options. The set of options, including the irrelevant options, can alter decision-making processes and result in preference reversal between the relevant options. This set of phenomena, referred to as context or decoy effects, has been extensively studied in value-based choice and has revealed important aspects of valuation and decision

processes. Recently, we have proposed that trial-by-trial adjustments of neural representations to the set of presented options can account for some context effects (Soltani et al., 2012). Interestingly, a new study has shown that context effects can also arise in perceptual decision making (Trueblood et al., 2013). Considering the prevalence of neural adaptation in most brain areas, we hypothesized that neural adaptation could contribute to both value-based and perceptual context effects. To test this hypothesis, we conducted an experiment to measure context effects in two different tasks using a within-subject design. In one task, human subjects selected between monetary gambles with different reward probabilities and magnitudes in order to maximize payoff (value-based task). In another task, subjects chose the line with the longest shadow out of a set of slanted lines, and were rewarded based on the size of the shadow (perceptual task). In both tasks, however, subjects were shown three options at the beginning of each trial, and one was removed at the time of choice (phantom decoys). Finally, in order to test the effects of neural adaptation on longer timescales, we measured context effects after increasing the range of option values in another value-based task (high-range manipulation). Firstly, we found within-subject decoy effects for both value-based and perceptual decision-making tasks. However, in the perceptual task, the decoys were effective only when presented next to the more horizontal line. Secondly, we found a significant correlation between the overall decoy effects in the two tasks, indicating that similar trial-by-trial adaptation could underlie context effects in two different types of decision making. Finally, we did not find any difference between decoy effects during the main experiment and high-range manipulation, illustrating that adaptation on longer timescales may not contribute to context effects. Overall, our results extend previous findings on the role of neural adaptation in sensory processing to the realm of irrational choice behavior, and further indicate that adaptation contributes to different types of decision making.

1-K-43 Independence of Irrelevant Alternatives in Decisions from Experience: A Challenge for Reinforcement Learning Models

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Normative decision theory assumes independence of irrelevant alternatives (IIA), stating that the relative preference of two options is independent of the choice set. Previous research demonstrated context effects (i.e., systematic violations of IIA) in decisions from description. They have been demonstrated across different domains, modalities, and even species. Their high relevance for the decision-making literature is reflected in the variety of process models that were proposed in order to explain them (e.g., Roe, Busemeyer, & Townsend, 2001). Yet, it remains unclear whether IIA is violated in decisions where the properties of the options have to be learned by trial-and-error. Such decisions are usually analyzed within the framework of reinforcement learning (RL). Importantly, existing RL models do not predict violations of IIA. The aim of the present study was thus to explore three different context effects in a typical RL setting. A total of 70 participants in three separate experiments completed two blocks of a repeated-play game with full feedback. Each block contained three options, where two of these three options shared the same outcome distribution across the blocks. The remaining third options were placed in order to elicit one of the targeted context effects, that is, the similarity effect, the compromise effect, or the attraction effect. After completing the two blocks, participants were prompted for explicit knowledge about the outcome distributions in a post-questionnaire. We found that participants' behavior systematically violated IIA. However, these violations were mostly not in line with traditional context-effect research. Instead, they were compatible with the similarity hypothesis, according to which similar options compete with each other for choice shares. These systematic

differences to decision from descriptions were further supported by a lack of explicit knowledge about the underlying outcome distributions in the post-questionnaire. We propose a new computational model, the accentuation of differences model (AOD), that generates context-dependent preferences by focusing attention on distinct outcomes. A rigorous model comparison combining post-hoc absolute fit as well as posterior predictive simulations implemented within a hierarchical Bayesian framework resulted in the AOD clearly outperforming RL models commonly used in the literature. The simulations matched the behavioral patterns qualitatively and had a close quantitative fit as well. The present study is the first to demonstrate systematic violations of IIA in decisions from experience as well as to offer a psychologically motivated model to explain such violations.

1-K-44   Simple Economic Choice in Large Choice Sets: An Investigation of Hick's Law
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We often have to choose from a large number of options (e.g. choosing a yogurt at the supermarket). Hick's Law predicts that the time that we need to make a choice should linearly increase with the logarithm of the number of options. However, this has yet to be tested in economic choice. Moreover, the neural mechanisms underlying this response time phenomenon remain unknown. We explore these questions using an eye-tracking experiment in which hungry subjects choose snack food items from large choice sets of varying size (N: 9-36). 51 hungry individuals participated in this experiment, which consisted of choice and rating tasks. During the choice task, subjects faced 200 randomly assembled sets of snack food items (sizes: 9, 16, 25, 36). For each set, subjects were asked to choose the item that they would like to eat most at the end of the experiment. Subjects had as much time as they wanted to make their choice. In the second task, subjects rated each of the 80 food items, which provided independent measures of their values. We find that subjects' response times do increase as a logarithmic function of choice set size, while their response accuracy remains constant and high, consistent with Hick's Law. In order to shed more light on these findings, we use the choice, response-time, fixation and value data to compare several computational models of the choice process in this class of environments. The results of this comparison show that the attentional drift-diffusion model qualitatively matches subjects' choice and response-time behavior and outperforms the alternative models on several important dimensions.

1-K-45   Neural signatures of rational and heuristic strategies: an EEG analysis
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This study explored neural underpinnings of decision strategy use in multi-attribute choice. We recorded EEG when participants performed a two-alternative probabilistic inference task, where they could acquire decision cues in a sequential manner and use this information to make the final choice. We analyzed participants' choices as consistent with either the normative Weighted Additive rule (WADD) or a simple heuristic Take The Best (TTB). Using a permutation-based single trial analysis with cluster correction, we analyzed amplitudes of EEG signal in response to consecutive decision cues. We looked for dependencies between EEG responses and the behavioral preference for either WADD or TTB. The preference for the WADD rule was associated with overall higher P300 amplitudes to decision cues. Moreover, for participants preferring WADD, the amplitudes of the P300 ERP component to consecutive cues were relatively similar, whereas for TTB users processing each consecutive cue was associated with substantial decreases in P300 amplitude. We interpret these findings in light of the current theories of

P300. Our results suggest that preference for either WADD or TTB has an early neural signature which reflects differences in attentional weighting of decision cues.

1-K-46   Loss aversion predicts reliance on goal-directed control

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Introduction Research on reward-based decision making has drawn a distinction between two different types of controllers: one that is slow to adapt, but cheap to use, embodying the common sense notion of "habit", and another that is flexible and goal-directed, but computationally expensive by comparison. These systems have been identified with model-free and model-based reinforcement learning, respectively. An active area of research aims to determine the factors that drive the degree to which individuals rely on each system. While some work suggests that the brain uses a sophisticated meta-controller, other studies are consistent with the idea that simple heuristics are also involved. These heuristics, however, have not been investigated. Here we test the hypothesis that the amount of model-based control an individual employs is related to loss aversion, a well-studied measure of how much more on average individuals weigh losses relative to gains. That is, individuals that are more sensitive to losses should be more willing to pay the cost of using the more sophisticated but costly model-based system in order to better avoid them. Results Fist, through simulation and an intuitive example, we demonstrate the utility of scaling model-based compared to model-free control as a function of loss aversion. We then present results from a large scale study (n=117) in which participants completed two tasks, one designed to measure the balance of decision system control, and another designed to measure loss (and risk) aversion. Using a Bayesian computational modeling procedure, we estimated each individual's reliance on each decision system, as well as their degree of loss and risk aversion. As predicted, we found that model-based but not model-free control relates to loss aversion. Risk aversion is unrelated either decision system. The results were robust under a number of different modeling assumptions. Discussion The current work was inspired by and raises interesting questions regarding the nature of information processing in anxiety, and in particular worry, an important component of many anxiety disorders, especially generalized anxiety disorder. Loss aversion has been independently linked to amygdala hyperactivity, decreased NE reuptake, differences in interoceptive ability, and to arousal measured via skin conductance, all correlates of anxiety. By comparison, the role of model-based control in anxiety has not been directly tested. The clinical literature describes worry as a goal-directed process aimed at preventing perceived future loss, suggesting perhaps that worriers are high in both model-based control and loss aversion.

L - Social Rewards & Social Preferences

1-L-47   Neural encoding of welfare during interpersonal utility comparisons

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People make decisions that have consequences for others on a daily basis. From a parent planning the meals for their family, to a politician deciding which area of a city to implement a government program in, the preferences of others are constantly traded against each other when we strive to make welfare-enhancing choices. Varying economic theories of interpersonal utility comparison offer insights into how we consider the preferences of others whose tastes differ from our own, suggesting that we can combine the utilities of others through the formation of empathetic preferences. However, the neural mechanisms behind this ability to consider other people's opposing subjective attitudes and make

choices that maximize overall welfare remain unknown. Here we show that people are able to make welfare maximizing choices by taking into consideration the preferences of two agents for different food items, even when those preferences differ substantially from their own, and the ventromedial prefrontal cortex (vmPFC) encodes overall welfare during interpersonal utility comparisons. Notably, the vmPFC showed increased connectivity with regions representing subjective value for dissimilar others, particularly the temporoparietal junction (TPJ), a region strongly implicated in perspective-taking, when subjective value gains were larger for others with dissimilar preferences. Our results suggest that the human ability to make interpersonal comparisons rests on the basis of empathetic preferences and the vmPFC encodes values that can drive welfare-maximizing decisions.

1-L-48   Cognitive dynamics of promise keeping vs. promise breaking
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We all make promises or commitments in our daily interactions with others. However, it is common experience that it is rather hard to follow through on every single one. Oftentimes people can benefit from not keeping promises and especially material incentives to cheat are ubiquitous in human societies. Therefore, deciding whether to keep or break a promise may generate cognitive conflict between the temptation to break it in order to gain some benefit or reward on the one hand and the commitments to fulfill one's word or "do the right thing", on the other hand. However, the presence of this cognitive conflict and its role in promise keeping/breaking is difficult to measure objectively with traditional behavioral methods, such as reaction times or self-reported ratings. In contrast, process tracing methods, such as mouse tracking, offer a promising way to measure such a conflict. Indeed, they are direct implicit measures of continuous streams of motor outputs that reveal real-time dynamics of cognitive processing with fine-grained temporal sensitivity. In the present study, we recorded mouse kinematics during a social interaction paradigm in order to investigate the role of cognitive conflict in promise keeping and promise breaking. Specifically, participants had to make a promise decision prior to a series of three trials about whether they always or sometimes plan to return money they will be entrusted with by an exchange partner. In the following trials, participants were free to keep or break this promise, resulting in different economic outcomes for themselves and the exchange partner. The results showed that when participants kept their promise the mouse trajectories were quite straightly directed toward the chosen option, indicating low attraction toward the unselected dishonest option. Conversely, when subjects broke their promise mouse trajectories were curved, indicating a higher attraction toward the unselected honest option. Interestingly, such differences in promise keeping vs. breaking were not observed in the reaction time analysis, indicating that tracing measures are able to capture fine graded differences unavailable to response time measurements. These results suggest that promise keeping and promise breaking are characterized by different levels of cognitive conflict. In particular, mouse kinematics revealed that promise breaking is associated with higher levels of conflict compared to promise keeping.

1-L-49   Cognitive Processes of Distributional Preferences: A Response Time Study
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There is ample evidence that people differ considerably in the strength of their preferences. We identify individual heterogeneity in social motives and selfishness in a series of binary three-person dictator games. Based on this identification, we analyze response time in another series of games to investigate

the cognitive processes of distributional preferences. We find that response time increases with the number of conflicts between individually relevant motives and decreases with the utility difference between choice options. The selfish motive is more intuitive for subjects who are more selfish. And heterogeneity in preferences is reflected in heterogeneity in the underlying cognitive processes. Our findings provide evidence for both, evidence accumulation models and dual-process theory. And our results also show that it is important to take heterogeneity of preferences into account when investigating the cognitive processes of social decision making.

1-L-50   Learning changes group identification

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Objective: An important aspect of human social behavior is the tendency to strongly identify with the groups one is part of. Group identification can motivate prejudiced behavior against out-group members, and even fuel intergroup conflict. Group identification is typically seen as trait-like, and relatively little is known about if and how it can be changed, despite its importance for intergroup behavior. We predicted that group identification can be changed by learning from interactions with in- and out-groups members. Method: We devised a novel experimental model of intergroup interaction, where the focal participant interacted with members of an in-group (Swiss) and an out-group (Middle eastern). The participants believed that the in - and out-group members made economic decisions that could result in the reception of electric shocks for participant. The probability of shock was identical for the in- and out-group. We measured trial-by-trial psychological closeness to the in- and out-groups, and shock expectancy ratings. Results: The results showed that psychological closeness, a proxy of group identification, changed predictably after both positive (omission of the shock) and negative (delivery of the shock) interactions. While the participants on average were closer to the in-group than the out-group, this difference diminished over time. Importantly, learning-related changes in closeness were moderated by both the participants' self-reported in-group identification, and racial bias. For participants high in racial bias, negative experiences with the outgroup specifically led to a larger distancing from the outgroup. Similarly, participants with a strong in-group identification changed their group identification more after both positive and negative experiences with the out-group than participants with less strong in-group identification. We used computational reinforcement learning to formalize the relation between pre-experimental attitudes, differential weighting of positive and negative outcomes, and changes in closeness to the in- and outgroups. Conclusions: Our results indicate that changes in group identification, measured as psychological closeness, are closely tied to reinforcements, providing a laboratory analogue of positive and negative intergroup contact. Furthermore, the results suggest that preexisting attitudes toward the in- and outgroup can lead to asymmetric weighting of the outcomes of interactions with the in- and outgroup, and thereby lead to either stronger or weaker identification with the groups. These findings will be supplemented with analyses of fMRI data.

1-L-51   Arginine vasopressin receptor gene (AVPR1A) is associated with human prosociality

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Objective: The arginine vasopressin receptor gene (AVPR1A RS3) has been recently associated with human prosociality. However, while one study found that the AVPR1A RS3 was related with altruistic behavior in college students, another study found an association between the same gene and selfish

behaviors in preschoolers. Since both studies used the same behavioral paradigm to measure prosociality, the Dictator Game (DG), but different populations, it is unclear whether these contradictory findings reflect differences in the samples studied, or whether the DG is a reliable tool to measure prosociality. In order to elucidate these issues we investigated the relationship between AVPR1A RS3 and prosociality with a large sample of human participants who played multiple economic games that pitted self-interest versus cooperation. Methods: Participants (435 subjects, 20~59 yo, women: 218) played a Prisoner's Dilemma Game (one-shot PDG, and sequential PDG), the DG (one-shot DG and iterated DG), the Social Dilemma Game (one-shot SD) and the Trust Game (one-shot TG as trustee role). All games played against anonymous partners. Prosociality was estimated as the average cooperative behavior across all games. Participants' DNA was extracted for measurement of AVPR1A RS3 allele length (base-pairs, bp). As previous studies showed a relationship between AVPR1A RS3 334-bp allele and antisocial behavior, we conducted a general linear model to investigate the effect of AVPR1A RS3 allele (334-bp versus other allele) on prosociality. Results: A significant relationship between prosociality and AVPR1A RS3 was found, where participants with the 334-bp allele carrier were significantly less prosocial than participants with the other allele types controlling for age and sex. Conclusions: This study showed the association between AVPR1A RS3 and a measure of human pro-social behavior which included aspects of cooperation, fairness and reciprocity, and which was independent of age and sex. Future studies may elucidate the neurophysiological mechanisms by which the gene AVPR1A RS3 modulates prosociality.

1-L-52   Validating an automated version of the rodent prosocial choice task

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Many of our everyday decisions happen in a social context. Thus, research is needed to clarify the influence of interaction between individuals on decision making. Humans often behave prosocially, i.e. they show actions that benefit others. There is growing evidence that non-human animals, including rodents, exhibit comparable prosocial behavior towards conspecifics. To test prosocial behavior in rats, we previously developed and validated a task that measures mutual-reward preferences while eliminating different egoistic motives that might confound decision making. In this rodent prosocial choice task (rPCT), pairs of rats, an actor and a partner rat, are trained in a double T-maze. An actor rat can freely decide whether to enter a left or a right choice compartment in their part of the T-maze, both yielding identical food rewards. Entering one compartment, the ?both-reward compartment?, results in additional delivery of a food reward to a partner rat that is facing the actor in the opposite T-maze, whereas entering the ?own-reward? compartment only yields a reward for the actor, but not for the partner. Since the payoff to the actor is always identical independent of its choice, a preference for the both-reward option can be considered the result of mutual-reward preferences. Despite its construct validity and easy setup, the current version of the rPCT requires a strong involvement of the experimenter, which makes it time-consuming and prone to human interference besides other unwanted confounding influences. Therefore, an automated version of the rPCT was designed, where opening and closing the doors of the choice compartments as well as the delivery of food rewards can be controlled through software, tracking the location of the actor and its partner. Advantages of this automated test execution is a very precise timing of reward delivery in addition to keeping the interaction between the rats and the experimenter minimal, which is both expected to improve reliability. Due to the novelty of the testing setup, execution and data quality of the ?automated? rPCT need to be validated and compared to the former ?manual? rPCT, acting as a reference. Currently we

are measuring prosocial behavior of rats using the two rPCT setups in parallel to grant the validity of the automated rPCT. Being able to validate and use an automated version of the rPCT would reduce testing duration and confounding influences of the experimenter, which leads to less discomfort experienced by the experimental animals and better data quality ? prerequisites for employing the rPCT for neurobiological measurements requiring minimal interference and high temporal precision.

1-L-53   **A behavioral and neural exploration of deception**

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Objective: Deception plays a big part in social interactions, from mundane white lies up to multimillion dollar frauds. While from a utilitarian stand-point, people should lie whenever they can benefit from it, in reality this is not the case. Previous work has shown that people incorporate into their decision process the consequences of their lie on other people. In this study, our objective is to identify behaviorally-relevant parameters that constitute the decision of whether to deceive another person. These parameters will later be used in a neuroimaging experiment to outline the neural correlates of dishonest behavior. Methods: 20 subjects completed a behavioral task called the 'Message Game', in which the subject (Sender) sent out either a profitable yet deceptive message (DM) or a truthful but not-as-profitable message (TM) to another subject (Receiver). The message stated which of four options is most profitable for the Receiver. Payoffs varied across trials, in order to assess individual sensitivity to different aspects of deception. At the end, one trial was randomly chosen and a corresponding message was presented to the Receiver, who then chose one of the four options, with the only information available to her being the Sender's message. Results: All Receivers chose based on the message they received from the Sender, demonstrating that our manipulation worked. When playing as Sender, participants sent a deceitful message on two-thirds of the trials (range: 10.7%-90%). We defined five potential motivations for deception: Self Interest (monetary value difference for the Sender between DM and TM); Regard for Other (monetary value difference for the Receiver between DM and TM); Inequality (Self Interest divided by Regard for Other); Efficiency (total payoffs in DM divided by total payoffs in TM); and Magnitude (sum of payoffs). We found using a multiple regression that all parameters except for Regard for Other had a significant impact on choices. However, subject-level analyses showed high variability in motivations: 70% of subjects were influenced by Self Interest (average $p=0.005$), 30% by Efficiency ($p=0.016$), 25% by Inequality ($p=0.03$), and both Regard for Other and Magnitude influenced 15% of subjects ($p=0.014$ and $p=0.015$, respectively). Conclusions: We found considerable inter-individual differences in the parameters that influence their decision to deceive another person. As a crucial next step, we intend to use this subject-specific behavioral variability to pin-point the neural substrates of the decision to deceive, in order to get a comprehensive view of the behavioral and neural processes which underlie dishonest behavior.

1-L-54   **Distinct Subregions within the Temporoparietal Junction and Posterior Cingulate Uniquely Track Prosocial Decision-Making**

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Many neuroimaging studies have shown that making decisions that affect other social agents modulates activation in a widespread network of regions, including the bilateral temporoparietal junction (TPJ), medial prefrontal cortex (mPFC), and posterior cingulate cortex (PCC). However, the traditional univariate nature of many of these studies may obscure more fine-grained or heterogeneous processing

within this network, preventing a more complete understanding of how the brain mediates decisions that influence others. To investigate the heterogeneity within this "social network", we applied multivariate analysis on functional magnetic resonance imaging (fMRI) data from 168 subjects during a social adaptation of a framing task that involved making decisions for the subject themselves, or for a charity of the subject's choice. By using a large sample, we were able to examine the robustness of any findings by using a split-sample replication scheme. We first examined the regions recruited when making decisions in a social context, that is, when making decisions on behalf of the subject's chosen charity. Consistent with prior research, we found a network of regions that exhibited greater activation during gambles for charity (compared to gambles for self), including the left TPJ (lTPJ) and PCC, as well as small regions of right TPJ and mPFC. We next examined the functional organization of these regions, and whether there is replicable heterogeneity within the regions of this network. To do so, we parceled the lTPJ and PCC regions, separately, using a probabilistic spatial independent component analysis (ICA). We then examined whether any of these components within lTPJ or PCC track prosocial (charity > self) behavior. Lastly, we extracted each component's time course via dual regression analysis, and regressed these time courses on prosocial framing decisions. Our analyses indicate that one subregion in both the lTPJ and in the PCC track social decisions (charity > self) in both independent split samples. Critically, these two subregions exhibit unique connectivity with regions in the social network after controlling for the influence of other subregions estimated from the ICA. However, despite both the lTPJ and PCC components tracking the same decisions in a social context and exhibiting similar functional connectivity, they did not exhibit temporal synchrony with each other. Using multivariate analyses, these results suggest that distinct regions within lTPJ and PCC are uniquely modulated by decision-making in a social context.

1-L-55   Facial Electromyography Reveals Dissociable Affective Responses in Social and Non-Social Cooperation

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While economic standard theory explains mutual cooperation in terms of rational strategic decision-making, empirical studies suggest that humans have a preference for cooperating with others. The current study investigated the specificity of these preferences for interactions with other humans, as compared to non-human agents, in an iterative PDG. In addition, we measured activity of the corrugator supercilii muscle with facial electromyography (EMG) as an indicator of spontaneous emotional responding during both social and non-social cooperation. We found that after free-riding (unreciprocated defection) participants switched more often to a cooperative strategy and showed increased corrugator activity (suggesting more negative emotional responses) when playing with a human relative to a computer partner. Our findings suggest that humans have a specific preference for cooperating with other humans and that social cooperation may be promoted by a negative affective evaluation of free-riding that is specific for human-human interactions.

1-L-56   Benefitting and punishing others: the dissociable impact of induced "care" and "power" motivation on economic interactions

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Objective In economic interactions, humans are known to frequently incur costs to benefit others (i.e., donating) and to "punish" those who do not (i.e., negative reciprocity). These two types of behaviors

have often been interpreted as stemming from one type of stable "prosocial preference", though recent studies have cast doubts on this assumption. One proposal is that economic punishments may be linked to the establishment of status and power. Here, we show that helping and punishing behaviors can indeed be manipulated separately, by inducing a "care motive" and a "power motive" respectively. Method 198 participants (mean age=27, 96 males) took part in one of three activities: in a "care induction" participants anticipated taking care of a group of puppies in the context of a therapy-dog training program. In a "power induction" participants were selected as "leaders" of an upcoming group project. In a "control induction" participants were to read a passage of text. We assessed self-reported feelings along a number of candidate motives before and after participants were told about these activities. Thereafter, while participants waited for the activities to take place, they took part in an allegedly "separate" study on economic decision-making, which involved a series of classic games (see below). We then ran a principal component analysis ("PCA") on the resulting behavioral indexes. Results The inductions successfully raised self-reported feelings of care and power in the corresponding conditions, albeit with noticeable gender differences. The first 2 principle components of the PCA separated between games involving benefits to others (charitable donations, 1st and 2nd movers in the trust game, and others), and games involving potential harm to others (2nd movers in the ultimatum game, 2nd/3rd party punishment games, and others). More importantly, participants in the care induction scored significantly higher on the first "benefitting component" than participants in the power condition or controls. On the other hand, in the power induction, males scored higher on the "harm component" than participants in the care condition and controls. Conclusions These results strengthen recent proposals that benefitting and punishing others are actually orthogonal dimensions of economic behavior and that they could be linked to a "care" and "power' motive, respectively. Our results also suggest that economic behaviors are driven by different motives that can be elicited as a function of different contexts and are thus not only the result of stable, context-independent preferences.

Monday August 29, 2016

A – Emotion & Affect

2-A-1   Affective Neuroscience meets Labor Economics: Assessing Non-Cognitive skills on Late Stage Investment on at-Risk Youth

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There is a common puzzle in the labor economic literature in which social programs ---i.e. educational or labor market programs--- that exhibit positive impacts on labor market outcomes seem, contrary to expectations, not to affect measures of non-cognitive skills (Kautz et al., 2014; Calero et al., 2014; West et al., 2015). Furthermore, recent meta-analysis concludes that studies using self-reported psychometric tests to proxy socio-emotional skills face potentially significant measurement errors that could lead to inconsistent impact evaluations (Almlund et al., 2011; Heckman and Kautz, 2014). Hence, this paper seeks to contribute in three dimensions. First, using novel data, it provides a rigorous estimate of the impact of a program to foster creative and life skills for at-risk youth in a formal educational setting in a developing country context. Second, using neurophysiological and survey data from field experiments, it asses the impact of that program on emotional state. Third, using neurophysiological recordings, it measures the program's impact on emotional responsiveness as a proxy for behavioral response (Loewenstein, 2001; DellaVigna, 2009). There are three main findings. First, I find that the program had significant impact on educational outcomes ---i.e. in both dropouts and SAT-like registration--- yet no

impact on the expected mechanism, such us socio-emotional skills or creativity measures, which is consistent with the findings in the labor economics literature referenced above. Second, I find significant impacts on emotional state ---in both arousal and valence indices--- from neurophysiological recordings. If emotional disposition can bias self-reported measures of non-cognitive skills, as suggested above (Querengasser and Schindler, 2014; Egana-delSol, 2016), this may account for the lack of evidence of an impact on non-cognitive skills ---the puzzle highlighted above. Third, program participation also reduces individuals' emotional reaction to negative stimuli ---one might say that it makes individuals more resilient.

2-A-2 Neuroscience & big data: Lawful patterns of approach/avoidance behavior across several thousand subjects

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Introduction: Recently, increases in computing power have revolutionized our ability to acquire large datasets on consumption and other human behaviors. These big data approaches offer the unique opportunity to transform the way we research neuroeconomics and, particularly, human preference behavior. Despite these advances, modern psychological research has remained largely rooted in in small-scale studies. Here, we investigate whether "big data" techniques can be used to conduct a psychological study on behaviors associated with activation within the Nucleus Accumbens, specifically human preference (i.e., approach/avoidance behavior) at the level of hundreds to thousands of people. Methods: We adapted a relative preference keypress paradigm to an on-line survey, in which subjects are shown a set of the International Affective Picture System (IAPS) spanning multiple categories (e.g., nature scenes, aggressive animals, men/women in bathing suits, etc.). Subjects (Study 1: N = 4,105; Study 2: N = 867) were asked to rate their subjective experience of each picture on a scale from -3 to +3. For each subject, we then computed measures of the standard deviation (σ) and Shannon entropy (H) of ratings within each picture category, and plotted these metrics against the mean rating (K) for each category. Results: We report four principal findings: (1) When H was plotted against K for each picture category, a value function emerged that closely resembles the value function established for prospect theory by Kahneman & Tversky. (2) When plotting rating σ against K, we observed a saturation function in which σ rises to a peak value for intermediate values of K before declining back to smaller values as K increases further. These saturation dynamics paralleled the decision utility from portfolio theory as elaborated by Markowitz. (3) Plotting entropy for negative ratings (H-) against entropy for positive ratings (H+) revealed a trade-off function that balances bundles of approach behavior against bundles of avoidance behavior. (4) The first three functions were all observed to scale from the level of individual subjects to the group level, and were consistently observed in two independent cohorts through a test-retest design. Conclusions: (1) We have shown that relative preference theory extends to human approach/avoidance behavior as measured through ratings, validating previous work with keypress paradigm. (2) We observed lawful patterns of preference behavior that scaled to the level of several thousand individuals, suggesting that "big data" approaches offer a promising and cost-effective new avenue for neuroscience research in human psychology and behavior.

2-A-3 If only I had chosen differently! EEG manifestations of comparison between received and alternative outcomes

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Behavioral research shows that following a choice, the outcome of the unchosen (alternative) option influences people's evaluation of their received outcome. Upward comparison - realizing the Alternative's Outcome (AO) was better than the Received Outcome (RO) - diminishes satisfaction; downward comparison increases it. ERPs studies tested if the Feedback-Related Negativity (FRN) and P3 are sensitive to outcomes comparison but methodological limitations hindered clear conclusions. Presenting both outcomes simultaneously at different locations didn't ensure that subjects paid attention to both stimuli. Presenting the AO first might have created biased expectations regarding the RO (Marciano et al., 2016). We overcame these issues using a novel paradigm, the Matrix Game, in which a single stimulus conveys both options' outcomes. We expected the FRN and P3 elicited by this stimulus to be more positive if the RO is a gain vs. a loss and less positive if the AO is a gain vs. a loss. Methods: 25 subjects saw a 2X2 matrix (Columns: +/-; Rows: +/-), and had to bet on Columns/Rows while EEG was recorded (66 electrodes). A coin then appeared in one of the matrix' cell. If subjects bet on Rows, they won 0.5 NIS if the coin appeared in the "+" row or lost 0.5 NIS if it appeared in the "-" row. If they bet on Columns, losing or gaining was based on the column in which the coin appeared. Thus, the location of the coin in the matrix simultaneously conveyed information on the AO and the RO. The amplitudes of the FRN and P3's were each subject to a 2 (AO: gain/loss) × 2 (RO: gain/loss) × 5 (electrodes - FRN: Fz, FCz, Cz, CPz, Pz; P3: Cz, CPz, Pz, POz, Oz) repeated-measure ANOVA. Results : FRN: The FRN was more positive when the AO was a loss vs. a gain. However, the FRN was not sensitive to the valence of the RO. These results, quite surprising given the literature on the FRN, could be explained by the complexity of the feedback, possibly requiring more time to be processed. P3: As expected, received gains elicited more positive responses than received losses, while alternative gains elicited less positive P3s than alternative losses. Conclusions: Using a novel task in which the RO and the AO were presented as a single stimulus, we found that the P3 was modulated by both outcomes. Importantly, the RO and the AO modulated the P3 in opposite directions, which suggests that the P3 doesn't reflect a mere summation of the two options' outcomes, but rather a downward/upward comparison process between what a subject received and what he could have received had he chosen differently

2-A-4   Emotion-induced changes in loss aversion are associated with altered neural value representations and functional connectivity of the amygdala

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Objective: Human decision making can be influenced by incidental emotions, i.e., emotions unrelated to the decision at hand. For instance, previous behavioral studies conducted by our group demonstrated that monetary loss aversion increases following the presentation of incidental fear cues. In the present study, we investigate the neural mechanisms of such emotion-induced changes in loss aversion. Methods: Twenty-five participants were primed with fearful or neutral faces before making binary choices over monetary gambles. Subjects accepted or rejected mixed gambles - i.e., gambles involving both gains and losses - while their neural responses were measured using functional magnetic resonance imaging (fMRI). We used behavioral modeling to estimate individuals' preference parameters. These parameters were then used to delineate subjectively appetitive and aversive gambles in the neuroimaging analysis and to investigate brain-behavior correlations. Results: We replicate our earlier behavioral finding of emotion-induced increases in loss aversion. In addition, we provide a mechanistic explanation for these effects on the neural level. In line with previous fMRI studies, we

observe a nonlinear response of the amygdala: increasing activity with increasingly appetitive as well as increasingly aversive gambles. The strength of this increase is correlated with loss aversion. Importantly, this response is modulated by the presentation of incidental fear cues. Specifically, the amygdala shows a stronger increase in activity to increasingly aversive gambles in the fearful compared to the neutral condition. Furthermore, this effect is positively correlated with emotion-induced changes in loss aversion. Moreover, we observe decreased amygdala-prefrontal functional connectivity in the fearful condition. Conclusions: Our findings reveal plausible neural mechanisms underlying emotion-induced changes in loss aversion, such as affectively modulated nonlinear neural responses in the amygdala, along with changes in amygdala connectivity.

B – Individual & Lifespan Differences

2-B-5   **Glucose metabolism modulates effort discounting in normal- and overweight women**

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Research in obesity suggests a link between the metabolic system and dopaminergic reward signaling. Intriguingly, emerging evidence suggests that dopamine impacts the motivation to engage in reward-seeking behavior. We propose that glucose metabolism, which determines how fast and efficiently energy can be stored and allocated, impacts perceived effort during instrumental behavior. This, in turn, may reduce the reinforcement value of the target (effort discounting). During an fMRI scan we observed instrumental behavior to obtain milkshake or monetary rewards in 19 young, healthy, normal- and overweight women after an overnight fast. We analyzed how this, as well as brain responses during reward receipt, related to HbA1c, a blood measure of glycemic control and metabolism. We observed that HbA1c had an impact on "wanting" ratings of milkshake rewards, but not on "liking" ratings. In addition, for milkshake, but not monetary rewards, HbA1c was associated with a stronger reduction of reward signals with increasing effort requirements in the nucleus accumbens and ventromedial prefrontal cortex. Moreover, instrumental behavior in individuals with low HbA1c was more strongly invigorated by the rate of past rewards. This suggests that glucose metabolism, by regulating energy supply, could influence a cost-benefit analysis comparing the energy invested with the energetic value of the reward. Our findings reveal an important mechanism that underlies the association of reward and effort in humans suggesting that the individual?s metabolism might shape the perception of effort costs.

2-B-6   **The development of self-control: inhibition and delay discounting**

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Diminished self-control is associated with various health risks (e.g., substance abuse) and developmental impulse control disorders (e.g., ADHD). Two frequently studied forms of self-control are response inhibition and delay discounting. Prior studies suggest that individual differences in delay discounting are independent from response inhibition. However, many of those studies used hypothetical delay discounting tasks, which may be insensitive compared with delay discounting tasks using real delays and rewards. Age-related differences in real and hypothetical delay discounting, and their associations with response inhibition were investigated from childhood to older adulthood (9-83 years, n = 166; 73 males). The current study showed a quadratic relationship between age and response inhibition; inhibition improved with age until adulthood and declined from approximately age 50 onward. Delay discounting showed no significant relationship with age. Congruent with the hypothesis and independent of age, enhanced response inhibition was associated with delayed reward choices on the real, but not on

hypothetical delay discounting tasks. These findings suggest that response inhibition is associated with the ability to wait for delayed rewards when these rewards are actually experienced. Real discounting tasks are arguably more emotionally salient than hypothetical tasks, and individuals therefore may require more self-control in order to resist the temptation of immediately available rewards.

C - Finance

2-C-7   The Neurofinance of The Home Bias Puzzle: A Dual-Process Model

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Objective This work seeks to advance knowledge on the behavioral underpinnings of the home bias puzzle by proposing a model, which builds on and integrates recent psychological and neuroscience findings on emotional memory, familiarity and recollection processes. The equity home bias - an investor's preference for domestic equities, despite documented gains in international diversification - is a major, yet poorly understood, puzzle in financial economics. While scholars have advanced explanations focusing mostly on accounts of national boundaries, geographic proximity, or information asymmetry, little consensus has been reached on the underlying mechanisms of an individual's financial decision making. Advancing a model able to predict why subjects express preferences for familiar assets rather than for the counterparts is compelling since substantial evidence recognizes a negative correlation between incomplete portfolio diversification (e.g., domestic/non-domestic assets) and lower returns. Model We propose that a financial "domestic cue" engages a subject's emotional memory, and in turn a dual process based on recollection and familiarity, distinctively. We contend that a) there is a direct, emotionally driven, effect of familiarity on the home bias; b) there is a direct effect on the home bias promoted by the decision-maker's cognitive sense of recollection with the cue. In line with other decision-making processes supported by neuroscience evidence, we suggest a "top-down" cognitive path in which recollection leads to the home bias outcome, and a "bottom-up" emotional stream in which familiarity plays a major role. The following supporting neural systems are involved in the processes: - Familiarity: Amygdala, vmPFC, hippocampus (see e.g., Yonelinas, 2004; LaBar & Cabeza, 2006) - Recollection: Hippocampus (see e.g.,Yonelinas, 2004). Contribution The quest to better understand the mechanisms driving the home bias is compelling for both theoretical and practical reasons. By substantiating our model with related neuroscience evidence we suggest the opportunity to disentangle the individual decision processes by analyzing directly the moment when relative wealth changes. This may clarify which behavioral mechanisms better predict home bias. Our framework shall implement normative theories of asset pricing and portfolio choice, in turn influencing financial regulatory policies in educating investors and helping them to make better investments. Ongoing research shall test our prepositions with behavioral and neuroscience methods.

2-C-8   Can brain activity predict stock prices?

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Objective: Functional magnetic resonance imaging (FMRI) activity in circuits associated with anticipatory affect (Knutson & Greer, 2008) has been used not only to predict trial-to-trial choice within subjects, but, more recently, aggregate choice as well (e.g., Venkatraman et al., 2015; Genevsky et al., 2015). Following these demonstrations, we sought to determine whether individual brain activity could inform predictions about changes in stock prices. Methods: While undergoing FMRI acquisition, participants (n=41) viewed trend lines reflecting updates of actual, historical, stock prices. All stocks were listed in

the S&P500 index, and price data was extracted online from Yahoo Finance in Winter 2015. Participants were not informed about the identity of the stocks or the selected time period. For each price update, participants decided whether they wanted to invest (i.e. bet that the stock price would increase the next day - if so they gained $1, but if not they lost $1) or not invest (i.e. not bet, in which case they received $0 for that round). Participants viewed price histories of 14 stocks, and made 10 investment decisions per stock (over 10 successive days per stock). Payout was based on performance, and no deception was used. Results: Activity in the nucleus accumbens (NAcc) predicted choices to invest within subject, replicating previous findings that brain activity can predict financial risk-taking on a trial-to-trial basis within individuals. When examining whether group brain activity could forecast changes in stock prices on the next day, results suggest that activity in the NAcc predicted stock price above and beyond the effect of the participants' own choices. This result remained significant after including standard financial measures used to predict stock market performance, such as slope or relative mean price over the past recent days. Conclusion: By developing a novel and incentive-compatible stock investment choice task, we not only were able to replicate previous findings that NAcc activity can predict individual risky choice, but we also obtained preliminary data suggesting that brain activity may predict stock prices above and beyond choice. Next steps include analyzing individual differences in performance to explore whose brain activity forecasts movement in stock prices best, and who performs optimally in real-world investing scenarios. Acknowledgments: This research was supported by the Neurochoice Initiative, which was funded by a Stanford Neuroscience Institute "Big Ideas" Grant

E – Risk & Uncertainty

2-E-9   Adaptive decision-making in mice with neuron-type specific inactivation of glutamate receptors in the dopamine system

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Bursting activity of dopaminergic neurons and subsequent phasic release of dopamine encodes reward prediction error, which by signaling the difference between actual and predicted outcomes promotes learning. It has been proposed that through modification of cortico-striatal synapses, prediction error signal is used to update the action values stored by striatal neurons. Taking into account that both, bursting activity of dopaminergic neurons and plasticity of striatal dopaminoceptive neurons depends on activation of glutamate receptors, we investigate the contribution of specific glutamate receptors (NMDA and mGluR5) in the dopamine system to adaptive decision-making. We used two mutant mouse strains with inactivation of either NMDA receptors in dopaminergic cells (NR1DATCreERT2 mice) or mGluR5 receptors in dopaminoceptive neurons (mGluR5D1-KD mice). Animals were trained in a two-armed bandit task in which they had to choose between two alternatives with different probability of reward delivery. Reward probability assigned to each alternative was constant within a block of trials, but changed across blocks. We found that during the first few sessions choices of richer alternative in mice lacking NMDA receptors in dopaminergic neurons were at a chance level, suggesting that mutant animals were unable to discriminate between alternatives. This was associated with reduced probability of 'win-stay' choices, decreased number of rewards obtained and longer choice latency. Nevertheless, performance of NR1DATCreERT2 mice improved in subsequent sessions and mutant mice reached the same level of performance as their wild-type littermates. No deficit in discrimination between alternatives was observed in mGluR5D1-KD mice. However, mGluR5D1-KD mice were less sensitive to reward delivery as evidenced by decreased probability of 'win-stay' choices and had longer choice latency during all testing sessions. Behavior of both strains generally obeyed the matching law,

indicating that mice made their overall choices based on the relative values of the two options. Taken together, our study reveal distinct roles of specific glutamate receptors located on defined neural cell types within the dopamine system in reward-based learning and indicate that NMDA-mediated signaling on dopaminergic neurons facilitates learning, while mGluR5-mediated plasticity on dopaminoceptive neurons modulates reward sensitivity.

2-E-10   Reward accumulation and the dynamics of risky choice

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Objective: Humans and other animals accumulate resources - or wealth - by making successive risky decisions. However, previous research focused mostly on the expectation or receipt of immediate monetary rewards, while disregarding the neural mechanisms underlying accumulation of wealth. Furthermore, it remains an open question how risk attitudes vary with changing wealth. Methods: Here, humans accumulated rewards in the fMRI scanner by accepting or rejecting successive monetary gambles within arbitrarily-defined temporal contexts. We employed logistic regression analyses and computational modelling of behavior to pin-point any potential shifts in risk attitudes arising from reward accumulation. We then investigated BOLD responses to wealth accumulation and receipt of reward, and correlated the neural findings with the computational models. Results: In behavior, risk-seeking gave way to risk aversion as wealth accumulated within a context. This change was also visible at the level of pairs of successive trials and confirmed by a negative weight of the current wealth level on the probability to accept a risky gamble in logistic regression. BOLD signals in the ventromedial prefrontal cortex (PFC) tracked the latent growth of cumulative economic outcomes. Risky behavior was explained by a computational model in which rewards prompt an adaptive update to the function that links utilities to choices, and decision signals predicted by the model were encoded in the dorsomedial PFC and varied with changing levels of wealth. Conclusions: These findings can be understood if humans have evolved economic decision policies that fail to maximize overall expected value, but reduce variance in cumulative outcomes, thereby ensuring that resources remain above a critical survival threshold.

2-E-11   Reason's enemy is not emotion: Engagement of cognitive control networks explains biases in gain/loss framing

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In the gain/loss framing effect, people are typically risk-averse when potential financial outcomes are framed as gains but risk-seeking when equivalent outcomes are framed as losses. Previous studies of the neural basis of the framing effect found amygdala activity during frame-consistent choices and dorsal anterior cingulate cortex (dACC) activity during frame-inconsistent choices. These results have been used to hypothesize that the framing effect is the result of an intrusive emotional bias that can be overcome with conscious effort (De Martino et al., 2006). An alternative explanation is that the framing effect results from behavioral strategies that involve low cognitive effort, without a necessary driver of emotion. In this study, we established a test of the emotion- and effort-based explanations of the framing effect by integrating large-sample empirical functional neuroimaging data with independent maps of brain networks derived from meta-analytic tools. We analyzed fMRI data from a final sample of 143 participants who performed a risky decision-making task that evoked a behavioral framing effect. The resulting neural activation during frame-consistent and frame-inconsistent choices was then

compared to each of the 2,592 term-based meta-analytic maps from the Neurosynth database using whole-brain correlation and partial correlation analyses. We found that neural activation during frame-consistent choices includes the amygdala but more strongly correlates with meta-analytic neural networks associated with the resting or default brain (e.g. state, default, resting, mode, PCC). Conversely, activation during frame-inconsistent choices best correlates with meta-analytic neural networks associated with the task-engaged brain (e.g. working, task, executive, frontal, maintenance, load). Our results overturn the previous conceptualization of the framing effect as being solely mediated by emotional, amygdala-driven processes. We show that the framing effect is not uniquely linked to that single region of interest and therefore cannot be wholly attributed to emotional processes. Rather, the biases of the framing effect correspond with differences in neural network activation that more closely reflect differential levels of cognitive engagement. Though our conclusions are specific to the gain/loss framing effect, future work should determine if they generalize to other decision-making biases that have been extensively studied using fMRI, such as loss aversion and temporal discounting. Furthermore, we show that data from neuroscience can provide novel insights into the processes that underlie well-studied decision science phenomena.

2-E-12   Self-Other differences in dynamic risk-taking
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Objective: Living in a social environment entails that we not only make choices for ourselves, but also for others. How we make decisions under uncertainty for others is still unclear and requires a better understanding of the processes that may underlie potential self-other differences in risk-taking. Much work has shown that individuals' decisions about uncertain outcomes are influenced by emotions. It is unclear, however, how decisions for others about uncertain outcomes may be influenced by emotions and whether this can account for differences in risk-taking when we decide for ourselves or for others. Here, we explored how decision-making on behalf of others can influence risk-taking and, in particular whether one's emotional state differentially affect risk-taking when deciding for ourselves or for others. Methods: Participants played the Columbia Card Task (CCT), which involved a 'cold'/static and 'hot'/dynamic version. In the cold version participants had to decide at once how many cards out of a total 32 cards they wanted to turn over, receiving no feedback until the end of the game. In the hot version, participants received feedback for every card they decided to turn, making it a dynamic version. Participants played both versions for themselves ('Self'), and for another person ('Other'). Results: In line with previous research (Figner et al., 2009) participants took more risk in the hot version as compared to the cold version (p=.001). A significant interaction between hot/cold version and recipient (Self or Other) was found (p=.004), showing that when choosing for the Other in the hot version, people turned over more cards as compared to for the Self (p=.06), whereas in the cold version risk-taking between Self and Other did not differ. Conclusions: These results show that deciding on behalf of others affects risk preferences, such that people are more willing to take risk when deciding for the other than for the self. Interestingly, we demonstrate that this is only the case in the hot version of the task when immediate feedback is given and risk dynamically increases, suggesting that one's emotional state differently influence decisions for ourselves and others. This is in line with previous studies showing that choosing for others showed reduced emotional responses toward outcomes. References: Figner, B. et al., 2009. Affective and deliberative processes in risky choice: age differences in risk taking in the Columbia Card Task. Journal of Experimental Psychology. Learning, Memory, and Cognition, 35(3), pp.709-730.

2-E-13   **Lifetime stress exposure correlates with ambiguity aversion**

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Although stress exposure is an inevitable part of daily life where decisions that involve risk and uncertainty are often made, reports of stress effects on decisions about uncertainty are equivocal across the literature. Research examining stress effects on these decisions have primarily focused on choices for which outcome probabilities are explicitly known (i.e., risk). However, decisions are often made when the probabilities of different outcomes are unknown (i.e., ambiguity). Here, we used a standard experimental economic paradigm that dissociates attitudes toward risk and ambiguity to assess how both acute and lifetime stress exposure affects economic decisions regarding uncertainty. Thirty-one healthy individuals first completed the decision-making task to characterize attitudes toward risk and ambiguity under non-stressful conditions. Self-reported state anxiety levels were collected using the State Anxiety Inventory before the choice task, and lifetime stress exposure levels was measured using the Stress and Adversity Inventory (STRAIN), a detailed inventory of encountered stressful life events, after the choice task. A week later individuals returned and were randomly assigned to repeat the decision-making task in the presence or absence of acute stress (cold-pressor or matched control task). Saliva was collected throughout each session to assay neuroendocrine markers of stress responses-- namely, cortisol and alpha-amylase. 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, suggesting that exposure to acute stress alone did not influence participants' attitudes toward risk or ambiguity. However, the STRAIN data revealed a negative correlation between two main indices of lifetime stress exposure (i.e., total count and severity of lifetime stressors experienced), and the proportion of ambiguous lotteries selected, indicating that higher levels of lifetime stress exposure were related to a lower willingness to accept ambiguous lottery offers. A similar association emerged between state anxiety and the proportion of accepted ambiguous lotteries. These effects were selective to decisions about ambiguity, as neither state anxiety nor life adversity was related to risky lottery choices. These findings suggest that higher states of anxiety as well as lifetime stress exposure may confer a lower tolerance for unknown outcomes during economic decision-making.

2-E-14   **Human information seeking behavior is influenced by reward in addition to the reduction of uncertainty**

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Objective: Humans seek to obtain information even in non-instrumental contexts in which they cannot act on the outcome, but the determinants of this motivation are not well understood. Normative theories such as the Kreps-Porteus (KP) model allow a preference for non-instrumental information only to the extent that it reduces uncertainty about the total future rewards. We challenge this axiom by testing if human information choice is additionally biased by the magnitude of the individual rewards that are revealed. Methods: We tested 142 subjects in an observing paradigm where they could choose to learn the payoff of one of two alternative lotteries without incurring any gain or loss. In each trial, subjects were presented with two lotteries that differed in their uncertainty (variance) and expected value (EV). Upon choosing a lottery, subjects received immediate feedback about the precise prize drawn from that lottery, but no information about the unchosen option. At the end of the experiment,

subjects received the sum of the prizes drawn from both lotteries, on one randomly chosen trial. To capture the heterogeneity in behavior, we fitted each subject's choices with a two-parameter model, where w1 measured the influence of relative uncertainty and w2 measured the influence of relative EV. Results: The values of w1 spanned a wide range but were positive on average, indicating that subjects tended to favor the early resolution of uncertainty. But contrary to the prediction of the KP model, w2 was significantly different from 0 in 39% of participants. The distribution of w2 values was strongly bimodal and partitioned into two groups of participants with, respectively, slightly positive and large positive values of w2. The average value of w2 was significantly positive across the entire sample and in each of the two groups, indicating a consistent effect of EV. Conclusions: Our results suggest that information seeking is motivated by a preference for revealing individual positive outcomes, above and beyond any resolution of uncertainty about the total reward that will eventually be earned. The positive values of w1 for many subjects suggest that early resolution of reward uncertainty is also a motivation, as allowed by the KP model; but the effect of relative EV requires a generalization of that model, to allow value to be assigned to resolution of uncertainty about individual sources of reward, not only uncertainty about total reward.

2-E-15 Normalization model offers an alternative explanation of the origins of endowment effect

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The traditional explanation for the endowment effect is loss aversion: People endowed with a mug demand more money to sell it than people who do not have the mug are willing to pay for it because losses loom larger than gains. Whether this is indeed the underlying cause of the observed differences between willingness to accept and willingness to pay has been the subject of a heated debate recently (List (2002), List (2003), Plott and Zeiler (2005), Engelmann and Hollard (2010), Isoni et al. (2011), Plott and Zeiler (2011)). In this paper we provide alternative and grounded in neuroscience explanation for the famous endowment effect. Over the past few years there has been growing interest in the notion that a representation involving divisive normalization (a canonical neural computation in sensory systems) encodes option value in the brain. The divisive normalization algorithm has been shown to rationalize behaviors previously labeled as anomalous in economic theory (e.g. Louie, 2013). There is growing understanding that anomalies in decision-making are in fact a result of an efficient value coding by a system that has limited neural resources (Glimcher, 2010; Woodford, 2012). In this paper, we show that if value-coding neurons in the brain used the divisive normalization algorithm, individuals would exhibit endowment effect under specific conditions (that closely resemble the conditions in all laboratory studies of this phenomenon). Importantly, in contrast to Prospect Theory, in our model the endowment effect does not universally occur. Consistent with evidence from experimental studies (Strahilevitz and Loewenstein, 1998; Marzilliet al., 2011; Heffetz and List, 2014), our model predicts a relationship between the existence and strength of the endowment effect, ownership history and beliefs about future ownership. Moreover, our model specifies how individual neural constraints and rational reward expectations determine when the endowment will and will not occur as well as when we should expect ?reversed endowment effect? to appear.

2-E-16 Trading off information against reward in time in a perceptual decision task

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When decision makers face multiple options, gathering more information about the options can, in principle, never hurt. However, it often takes time to collect information. Knowing that time is costly but information is helpful, the timing of a decision becomes an extremely important question. In this study, we investigated decision timing by asking how people balance the cost of time against the additional information they can receive through time. Methods. In a perceptual decision task, subjects were instructed that a box consisted of a total of 100 red and green balls. Unbeknownst to the subjects, on each trial, either there were more green balls or more red balls. The subjects' task was to guess which ball - red or green - had more in number in the box. In order to provide information about the box, we sampled from the box and sequentially presented the samples as red or green dots on the screen. The odds of red was either 55/45 or 45/55. A key manipulation of the task was the amount of monetary gain subjects would receive for making a correct response. Here, we introduced time cost by implementing a decreasing reward function. That is, on each trial, the gain associated with a correct response decreased over time. The subjects can freely choose when to make a response. The question is, can he or she balance the benefit of time - accumulating more dots over time leads to better performance - against the cost of time? For each subject, the experiment consisted of 14 sessions that spanned 3 weeks. Each subject completed a total of 2000 trials. Results. In order to maximize reward earned, subjects in the decreasing-reward task had to appropriately balance the gain in performance that time brought against the cost of waiting manifested by decreasing rewards. In other words, the subjects had to decide 'when' to stop collecting information and make a choice. We found that subjects' decision time were typically slower than the decision time predicted by an ideal decision maker that takes into account the cost and benefit of time. To explain the suboptimal pattern, we tested 3 models: risk aversion (RA), loss aversion (LA), and probability weighting (PW). Both RA and LA models failed to consistently describe the data. In contrast, a probability weighting function that was convex in moderate to large probabilities successfully described suboptimal patterns across subjects. This indicated that subjects underweight moderate to large probabilities and that the marginal gain in probability of success increased as a function of time. This made waiting become extremely attractive, even though the benefit of waiting was rather limited.

2-E-17 Risk for me or risk for others, decision for strangers reduce the degree of loss aversion
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Decision under risk is pervasive in our daily life and have been a focus of economics, management science and psychology for decades. Empirical studies observed that, in general, individuals demonstrates a behavioral tendency of loss aversion, namely, losses exert a greater hedonic impact than equivalent gains. Subsequent neuroeconomic studies indicates the emotional system plays an indispensable role in such a decision process. Recently, decision for others under risk gradually become a topic with increasing attention both in the field of economics and psychology. Nevertheless, few studies have investigated to what extent the intimacy among individuals modulates the degrees of loss aversion. In order to address this unexplored question, recruited subjects are instructed to make binary risky choices for themselves, their closest friends as well as unfamiliar counterparts under the gain, mixed and loss conditions. Modelling under the framework of prospect theory (Kahneman, Tverskey,1979;Tverskey, Kahneman,1992), econometric analysis reveals that subjects prominently exhibit a tendency of loss aversion, which suggests the fact that losses looms larger than gains irrespective of whether the financial outcome is for themselves or others. Intriguingly, we observe that decision for unfamiliar others with relatively farther social distances considerably reduce the degree of loss aversion but this doesn't hold true for their close friends. Extending the previous neuroeconomic

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findings for the empathic responses to vicarious financial gains and losses, it implies that an attenuated emotional involvement shapes the reduced degree of loss aversion.

F – Intertemporal Decision-Making & Self-Control

2-F-18   The role of time ambiguity in intertemporal choice

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Objective: In everyday life, people frequently face choices between a sooner-smaller (SS) reward, e.g., enjoying your favorite high-caloric food now, versus a later-larger (LL) reward, e.g., having a slim figure in the future. Although people often have imprecise information about the timing of outcomes (e.g., when exactly would one have that slim figure?), standard intertemporal choice paradigms typically provide exact timing information. Therefore, the current study investigated how ambiguity in the timing of outcomes influences intertemporal decisions. Methods: We developed a novel intertemporal choice task in which subjects made decisions between SS and LL outcomes in the presence of systematically varying levels of time ambiguity while undergoing functional Magnetic Resonance Imaging (fMRI). Trials presented either exact information about outcome delays (e.g., 5 weeks from now), or imprecise information that ranged between 4 weeks (e.g., 3 to 7 weeks from now) and 8 weeks (e.g., 1 to 9 weeks from now). Time ambiguity was introduced to either the SS, LL or both. To reduce variation in choices due to individual differences in discounting and more effectively isolate the effect of time ambiguity, we used indifference pairs (e.g., pairs of SS and LL outcomes that are matched on subjective value). Results: Participants were significantly less likely to choose an option when its outcome timing was ambiguous compared to when it was precise, indicative of time ambiguity aversion. Consistent with its role in subjective value computations, we found significantly decreased activity in ventromedial prefrontal cortex (vmPFC) during decisions with time ambiguity (compared to decisions without time ambiguity), and this effect was enhanced in subjects that showed greater levels of behavioral ambiguity aversion. Furthermore, we observed increased activation in the intraparietal sulcus (IPS) during decisions with (versus without) time ambiguity, possibly reflecting increased processing demands under conditions of uncertainty, as this region has previously been implicated in supporting inexact calculations and numerical estimations in probability ambiguity. We are currently conducting analyses to identify brain networks through which time ambiguity exerts its effect on choice (using psycho-physiological interactions (PPI) and mediation approaches). Conclusions: To our knowledge, this is the first study to have investigated ambiguity aversion in the domain of intertemporal choice. Time ambiguity is ubiquitous in the real-world, especially regarding long-term goals, thus time ambiguity likely contributes to short-sighted decisions above and beyond delay discounting.

2-F-19   Incentivized inhibition: The role of connections from the ventrolateral prefrontal cortex to the anterior insula.

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Over a decade of human and monkey studies have shown that the structural integrity of the right ventrolateral prefrontal cortex (vlPFC) is critical for motor inhibition. Most of these studies, however, have not examined inhibition under incentivized conditions. In this study, we imaged structural connections from vlPFC, and functional brain activity associated with motor inhibition to earn monetary

incentives. Although subjects had faster motor responses for high incentives, they showed better motor inhibition for no incentive. We then identified a white-matter tract connecting the vlPFC to the anterior insula (AIns), and also replicated characterization of a tract connecting the AIns to the nucleus accumbens (NAcc). Individual differences in the coherence of both of these tracts, in addition to functional brain activity, were independently associated with successful inhibition for high incentives. This work not only suggests that knowledge about brain structure can help guide models of brain function and behavior, but also highlights potentially dissociable roles of the vlPFC and AIns in incentivized inhibition.

2-F-20   Assumptions of linear utility systematically bias estimations of impulsivity

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Objective: The study of human impulsivity through measures of temporal discounting (TD) is a widely used approach in the fields of psychology, behavioral economics and more recently in medicine and computational psychiatry. Individual differences in TD are a topic of intense research in these studies, but models of TD traditionally assume a linear utility function in their estimation of discount rates (DRs). However, results from our laboratory have shown that both healthy individuals and patients with substance use disorder deviate from risk neutrality and exhibit high inter-individual variability in their risk preferences. The assumption of linearity of their utility function can lead to differences in the estimation of DRs. In this study we characterized subjects' preferences for risk and time in two separate incentive-compatible choice tasks. We compared two models: a model that incorporates a normative estimate of the curvature of an individual's utility function with a non-normative hyperbolic utility function and a "standard" hyperbolic-only model that does not. Methods: Forty-three participants from the general community were recruited to attend 1-5 sessions during which they completed both a risk attitude task (RA) and an intertemporal choice task (ITC). For the RA task, subjects chose between a certain gain of $5 versus a variable lottery that ranged from $4 to $66 with a 25%, 50% or 75% probability. For the ITC task, participants chose between an immediate monetary reward ($2, $5 or $15) and a larger reward that came with a delay (ranging from $7 to $66 and from 4 to 150 days). At the end of each session, one of the trials from both tasks was randomly selected for realization. We estimated participants' DRs with a "standard" TD model and with a modified hyperbolic TD model with an exponential parameter that accounts for risk preferences. The models were compared using AIC and BIC scores and cross-validated log likelihood comparisons. Results and conclusions: The TD model that includes a risk sensitivity parameter outperformed the "standard" TD model - accounting for significantly more variance in the data. Furthermore, when risk preference deviates from neutrality, the DRs derived from the standard model are systematically different: In risk-averse individuals, impulsivity appears higher with this approach, while DRs appear lower in risk seeking individuals. This finding has important implications for the interpretation of differences across individuals and groups. It is particularly relevant to the ever-growing number of studies concerned with impulsivity in disorders with diverse risk preferences like addiction, ADHD, anxiety and PTSD.

2-F-21   Disrupting the temporo-parietal junction reveals role of overcoming self-centeredness in delay of gratification

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The ability to delay gratification is an important cornerstone of individual and societal well-being.

Prevalent neural models of intertemporal decision-making focus on the role of a frontal control network in guiding impulsive choices. However, intertemporal choices correlate also with activation in the temporo-parietal junction (TPJ), which is often ascribed a role in social cognition. This raises questions regarding the functional role of the TPJ in temporal discounting, and whether it can be reconciled with social accounts of TPJ functioning. Here, we used transcranial magnetic stimulation (TMS) to assess the role of the TPJ in intertemporal and interpersonal decision-making. Disrupting the TPJ increased discounting of delayed and shared rewards by impairing the ability to overcome the egocentricity bias of the present self. We conclude that a common neural mechanism related to egocentricity bias contributes to temporal and social discounting and that the TPJ plays a crucial role in implementing this mechanism.

G – Computational Modeling

2-G-22   Forming a Desired Belief: A Computational Account

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How do we form beliefs about hidden states? Past work suggests that such inferences are guided not only by the available evidence but also by the desirability of that evidence. However, the dynamics of this process are largely unknown. Here we use an accumulator model--the drift diffusion model--to describe the formation of such beliefs and the role of valence in this process. In a series of experiments we ask participants to play a slot machine which can either be in a desirable state (more likely to produce gains than losses) or undesirable state (more likely to produce losses than gains), and require them to report which state they believe the machine to be in as they play. Markedly, participants were more likely to report the slot machine as being in a desirable state than an undesirable state than the objective evidence warranted, and were faster to reach desirable conclusions, despite being incentivized for accuracy. Applying a drift diffusion model to this data revealed (1) a larger drift rate towards desirable beliefs than undesirable beliefs and (2) a response bias towards desirable beliefs. This suggests humans both accumulate desirable evidence faster and have a predisposition to hold desirable beliefs. The results offer a computational account of the role of valence in belief formation.

2-G-23   Golf Theory, a geometrical modeling approach to decision process

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Objective: Modelling the dynamics of decision making processes is crucial to understanding how decisions are formed based on noisy sensory input. Existing models such as decision field theory (DFT) explain a wide range of phenomena such as the anchor effect but others are unexplained or indistinguishable. Here we propose a new theory for decision making (DM) based on geometrical modeling which we call Golf Theory (GT). GT can explain a vast number of phenomena in decision making process, including the endowment and decoy effects, ambiguity and anchor effects, besides hindsight bias. In addition, GT proposes a reasonable explanation on the delay between appearance of unconscious determinants and decision in a free motor DM. Methods: In GT, the decision is represented by the trajectory of a ball moving across a deformable plane, the decision plane (D-plane). The D-plane rests on two other layers, a medium space and a perception plane (P-plane). The P-plane is a rigid plane that captures the perceived information, attributes, and other features of all options. It is activated according to each option's valence causing local attractors. The D-plane is deformable and responds to the force of attractors on P-plane. Finally, an intermediate layer captures additional decision parameters. It acts as a low pass filter, which can capture temporal delays as well as eliminate noise

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originating in the sensory data. The trajectory of the ball on the D-plane represents the decision process. Results: Using our model, we generate several cognitive biases such as the endowment effect and the anchoring effect. The two effects may create similar trajectories for the decision ball. However, our model hypothesize that they are generated by different cognitive processes. While the endowment effect arises from a deformation of the decision plane, the anchor effect is a result of the initial activation of the perception plane. We show how GT can be considered as a geometrical extension on DFT by considering the latter as an activation function of the P-plane. Conclusion: Here we mainly focused on anchoring and endowment effects, but GT is a general theory, which may explain a wide range of phenomena in DM. GT is an example of adopting powerful ideas from geometry in order to first visualize the decision process and then see how using a simple physically intelligent structure can help us to model complex systems such as decision process in the brain.

2-G-24   Discreteness and Delay in Adjustment to a Changing Environment: Experimental Evidence

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Objective: We conduct a laboratory experiment to shed light on a central issue in macroeconomic modeling: the nature of "stickiness" in behavior (for example, in the prices set by firms), and delay more generally in adjusting behavior to what would be optimal in the current environment. To this end, we modified an existing probability estimation task in order to observe subjects' behavior in a task requiring continuous reporting of their current estimate (allowed to take any of a continuum of values) of a hidden state variable. Methods: On a computerized task, subjects estimate the hidden probability of green rings in a box containing green and red rings. This hidden probability changes in a stochastic and unsignaled manner. At any given point in time during the task, subjects were able to draw rings from the box and indicate their estimate of the hidden probability using a slider bar. Importantly, subjects were instructed with all relevant details of the data generating process. This includes the probability distribution behind the possible hidden probabilities and the probability of this parameter changing at each draw. In addition, subjects were incentivized to report their true estimate of the hidden probability following every draw. Results: Average errors in estimation are relatively small and changes in the hidden probability are detected relatively quickly; nonetheless, our subjects depart from the optimal Bayesian benchmark in meaningful ways. While the current "gap" between the Bayesian ideal observer's estimate and the subject's current estimate is an important predictor of whether the subject adjusts her estimate at any point in time, this gap is a poor predictor of the resulting adjustment magnitude. As in actual economic data, subjects frequently made adjustments in discrete jumps rather than after each new observation. Moreover, subjects adjust their estimates by both large and small amounts, resulting in a wide range of adjustment sizes. In addition, subjects exhibit a number of general response biases including a preference for reporting round numbers. Conclusions: Subjects' performance contains features inconsistent with many models proposed in the economics literature, including the Bayesian ideal observer model; simple econometric forecasting models, such as "constant-gain" estimators; the "Ss model" of optimal adjustment with a fixed cost of adjustment; the "generalized Ss model" proposed by Caballero and Engel; the "sticky information" model of Mankiw and Reis; and the "rational inattention" model of Sims. We document features that a more general model of discrete adjustment must include in order to be consistent with our data.

2-G-25   **Studying value guided decision making through model-based multivariate fMRI**

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Objective: The combination of functional neuroimaging (fMRI) with reinforcement learning (RL) models has led to much progress in understanding the neural basis of value-guided learning and decision making (O'Doherty et al. 2004). However, fMRI analyses based on RL models have largely been restricted to univariate analyses and have not made use of the advantages of multivariate analyses, with the few studies attempting to identify multivariate neural RL signals resorting to model-free analyses (e.g., Vickery et al. 2011). One obstacle for combining multivariate and model-based approaches is the reliance of standard multivariate approaches on classification techniques that require assigning discrete classes to the data, which is not feasible for continuous (and potentially multivariate) predictions made by RL models. Here we combine model-based fMRI with a multivariate approach that does not depend on classification, in order to investigate multivariate representations of prediction errors and multi-attribute values. Methods: We re-analyzed data from a multi-dimensional bandit task in which participants made repeated choices between three objects, each consisting of three features (color, shape and texture). Within each game, participants had to learn from feedback which dimension was predictive of reward, and within it, what feature was most rewarding. To assess the neural representations underlying this process, we modelled participants' choices using an RL model (Niv et al., 2015) and tested for multivariate neural correlates of the resulting trial-by-trial predictions with cross-validated multivariate ANOVA (Allefeld & Haynes, 2014).Results and conclusions: A standard univariate analysis revealed evidence for reward prediction errors (RPEs) in bilateral ventral striatum, and effects of value in vmPFC. Using our novel multivariate method, we found evidence for RPE-related brain signals in a far more extensive network of areas, including the ventral striatum, OFC, vmPFC, ACC, left insula, superior parietal lobule and inferior parietal cortex. This finding, in line with previous studies indicating a widespread representation of RPEs, underlines the added power of using our multivariate model-based method. The multivariate map of value representation also indicated a set of areas that were not uncovered by univariate analyses, including lateral PFC. Taken together, these findings establish the benefits of our approach and provide the basis for the investigation of new questions about the neural encoding of higher dimensional decision variables using fMRI. Acknowledgements: This research was funded by the Princeton/Humboldt strategic partnership program.

H – Game Theory & Strategic Interactions

2-H-26   **Serotonin depletion is associated with increased aggressive behavior in the Hawk-Dove game**

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Objective: The neurotransmitter Serotonin (5-HT) is known to have a crucial role in the regulation of human behavior and diverse physical functions. Previous research, for instance, could show that lowering 5-HT levels promotes retaliation to perceived unfairness and decreases cooperative behavior. Based on these findings, we predicted that a reduction of cerebral 5-HT levels would also influence strategy choice in the Hawk-Dove game. The Hawk-Dove paradigm illustrates a conflict situation between two persons with two strategy alternatives: (1) an aggressive strategy (Hawk) and a cautious strategy (Dove). We hypothesized that reduced 5-HT levels would lead to increased choice rates of the aggressive (risky) Hawk strategy. Methods: 49 healthy young males (treatment: n=25; control condition: n=24) took part in our experiment. We induced a temporary reduction of brain serotonin levels using

the acute tryptophan depletion method (ATD). Therefore, participants of the treatment group consumed an amino-acid drink that lacks tryptophan (the precursor of serotonin); whereas the control condition received a drink that contained tryptophan. After a delay of 5 hours, participants played a 2x2 Hawk-Dove game without feedback. Participants played variations of the Hawk-Dove game that differed in the incentive to choose the Hawk strategy. In addition, we elicited subjects' risk preferences using the Holt and Laury (2002) procedure. Results: As expected, our results indicate that reduced 5-HT levels promote significantly increased choice rates of the aggressive Hawk strategy. This effect is more pronounced for games with high incentives to choose the Hawk strategy. However, we found no significant differences in risk attitudes between the ATD and the control group. Conclusions: Our study provides evidence that a lowered serotonin level is associated with increased aggressive behavior in social dilemmas. We were also able to show, that the risk attitude remains unaffected by ATD. Thus, we can rule out changes in the risk attitude as an explanation for the more frequent choice of the more risky Hawk strategy in the ATD group.

2-H-27   Proposer's fairness in the Ultimatum Game: An Event Related Potentials study

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Objective: Willingness-to-share is tested in the Ultimatum Game (UG), where the participants iteratively play a role of proposer and responder sharing a virtual amount of money. It is rationale to expect that the proposer would offer the smallest possible amount and the responder accepts any amount. Responders' behaviour and brain activity have been extensively investigated, but proposers' strategies and event related potentials (ERPs) received less attention. Offers of large amounts may be driven by fear and guilt, where fear is more related to the perceived consequences of having one's offer rejected, and guilt is more related to concerns for the opponents' outcomes. Our study is aimed at testing whether proposers' small amounts are associated with different brain activity compared with proposers offering large amounts. Methods: In the present study, 32 participants played alternatively the role of proposer and responder in block series of the UG, while we recorded their electroencephalogram (EEG) and analyzed the ERPs triggered by the decision-making events. We separated the trials of the proposers when offering a low (unfair or wretched, up to 40% of the amount) and high (fair or prodigal, more than 60% of the amount) amount. Our analyses were focused on ERPs recorded in the frontal (Fz) and parietal (Pz) electrodes. Results: We found significant differences between the ERPs components evoked by wretched or prodigal offers at all trigger events that we analysed, in particular when the proposer is requested to make an offer and when the proposer pressed the key associated with the offered amount. At the first trigger the N2P3 complex wave was characterised by larger latencies and amplitudes in association with prodigal offers. In the frontal sites the amplitude differences were larger than at parietal sites, but the latency increase was larger at parietal than frontal locations. Prodigal offers were also characterised by the appearance of two distinct components P3a and P3b. Conclusions: In our study the same participants played both roles of proposer and responder, thus testing the hypothesis whether "Homo reciprocans" and "Homo Economicus" are in contrast. Our results contribute to a better identification of brain circuits involved in processing fair or wretched offers against willingness-to-share decision making. Acknowledgements: This study was funded by the Swiss National Science Foundation, grant # CR1311-138032.

2-H-28   Sophisticated attention comes into play: linking relational representation in reasoning and strategic sophistication in games

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Objective:Recent findings suggest the existence of individually consistent patterns of visual information acquisition based on subjective levels of strategic sophistication in interactive games (Polonio et. al, 2015). However, little is known about the interplay between relational representation and the level of strategic sophistication achieved by human players. Our goal is to investigate whether it is possible to predict player behaviour in games by analysing how participants acquire relational information in a conditional transitive reasoning task. Methods:We recorded eye movements of 61 participants while performing a novel conditional transitive reasoning task and playing 48 matrix games. In the reasoning task, subjects were presented series of conditional relations of the form "if A then B" connecting pairs of symbols; moreover, such pairs could be linked by transitive relations. Participants had a limited amount of time to acquire all the relevant pieces of information in a series before choosing the symbols that necessarily followed a given state. Furthermore, participants played three classes of one-shot games characterised by different dominant strategies. We finally analysed the patterns of visual information acquisition implemented by participants during the reasoning task and we compared them with the type of analysis observed in games. Results:In the reasoning task, the speed of the acquisition of relational information as well as the contingent relevance of the between-symbols transitive saccades predicted accuracy, especially in trials with non-linear relations. We also found an index that reflects the cognitive effort employed by participants to represent specific relations, based on the stability of the duration of fixations. Interestingly, these parameters predicted the level of sophistication adopted in interactive game playing. In particular, participants who were fast and efficient in acquiring relevant information during the reasoning task exhibited a more sophisticated analysis in games. More specifically, they followed a consistent and dynamic pattern of information acquisition which took into account the payoffs of the opponent in a strategic fashion. Conversely, participants who were less efficient in representing relational information deviated more frequently from an optimal payoff analysis in games. Conclusions:Participants who were rapid and efficient in acquiring relational information showed a higher level of strategic sophistication in interactive games. These findings establish a link between attentional indices of efficiency in information representation and the level of sophistication in interactive scenarios.

I – Learning & Memory

2-I-29   Human Striatum Represents Bayesian Surprise, Not Prediction Error, in Categorization Learning

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Objective: Humans naturally group the world into coherent categories defined by membership rules. While it is possible to learn these rules using stimulus-response associations, humans also have the ability to explicitly reason about rules. We sought to determine whether the striatum, which reliably shows activation that scales with reward prediction error and is thought to be a part of the brain's reinforcement learning system, would also show prediction error responses in a task where people learn explicit rules. Methods: We acquired functional magnetic resonance imaging data from subjects while they learned the category labels of stimuli with deterministic feedback. The stimuli had three dimension (shape, color, texture), and each dimension had two possible feature values. Subjects learned rules in blocks ranging from simple (e.g., blue stimuli are category 1) to complex (e.g., blue and square or checkered are category 1). We fit a series of reinforcement learning models that learns rules implicitly as

well as a Bayesian rational rules model that reasons explicitly over rules. Results: We exploit a difference in the learning signals between reinforcement learning models (reward prediction error) and Bayesian updating (surprise). Reward prediction error is a signed learning signal that is larger for positive than negative feedback. In contrast, surprise in our task was generally larger for negative feedback. In the neural data, we find greater BOLD signal responses to negative relative to positive feedback in both the striatum and ventral tegmental area. This pattern of responses is inconsistent with reward prediction error signaling. Further, we find that activation in the striatum scales parametrically with the Bayesian surprise signal. We propose that the striatum updates stimulus and action values, rather than representing learning signals per se. Although value updating and prediction error are perfectly correlated in reinforcement learning models, rule updating and surprise are not. We demonstrate that the striatum and caudal inferior frontal sulcus (cIFS) activation varies parametrically with rule updating and exhibits functional connectivity during feedback. Conclusions: We conclude that the striatal feedback response does not represent prediction error as part of a reinforcement learning algorithm. Rather, its response scales with the relevant learning signal underlying learning because it is involved in updating a model of stimulus-response demands of the environment. We conclude that the striatum, in cooperation with the cIFS, is specifically involved in updating the values assigned to rules, rather than representation of error.

2-I-31   Physiological markers during adaptive learning in a changing environment
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Objective: In volatile environments characterized by discrete change points, beliefs should be updated more quickly, when the new evidence is more surprising given current beliefs (i.e., change-point probability is high), and when there is greater uncertainty about the current state, relative to irreducible noise (i.e., relative uncertainty is high). Previous work has established that pupil-linked arousal systems track both normative factors. However, three issues remain to be clarified. First, do change-point probability and relative uncertainty affect other measures of physiological arousal as well? Second, do pupil responses to change points reflect surprise per se, or surprise that specifically signals that beliefs need to be updated? Third, recent studies have found that reward exerts a non-normative effect on belief updating. Does reward affect physiological arousal as normative factors do? Methods: Twenty-four participants performed a predictive inference task that required them infer an environment?s state (a number between 0 and 300) based on noisy evidence. On each trial, they observed a number drawn from a Gaussian distribution with mean at the state. Occasionally, the state changed without notification and participants had to infer the current state based on new observations. Subjects were rewarded on a randomly selected half of the trials, with the reward received depending on the prediction accuracy. To elicit task irrelevant surprise, an oddball sound accompanied new observations, at a frequency matched to the rate of change points. During the task, pupil diameter, skin conductance, heart rate and respiration rate were recorded. Results: First, consistent with previous results, pupil diameter encoded both change-point probability and relative uncertainty. No other physiological measure reflected both normative factors. Furthermore, only pupil diameter predicted trial-by-trial learning rates. Second, task-relevant surprise affected pupil diameter only, while perceptual oddballs (task-irrelevant) affected skin conductance and heart rate. Third, reward not only affected belief updating but also increased pupil diameter and skin conductance. Conclusions: Among physiological measures, only pupil diameter encoded all factors that influence learning (change-point probability, relative uncertainty, and reward) and predicted learning rates. The effect of change-point probability

could not be accounted for by surprise alone, as task-irrelevant surprise elicited a different pattern of physiological responses. These results suggest a unique role for pupil-linked arousal systems, associated with the noradrenergic system, in adaptive learning.

J – Valuation & Value Systems

2-J-32   Bias in valuation of economic information and its neural correlates

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Introduction: To make good decisions, people ubiquitously try to acquire relevant information. Information acquisition is itself a challenging decision, because information may or may not be worth its cost (e.g., effort, time, money). This challenge can be solved by calculating value of information. Under normative decision theories, information value only comes from the opportunity it gives agents to improve their decisions, and is calculated as the difference between the expected values of an informed action and an uninformed action. Previous studies have shown that, even though subjective value largely conforms to such prediction, there is systematic deviation left unexplained. Moreover, while neural basis of valuation of monetary reward and objects have been well studied, that of valuation of information is basically unknown. This study aims to provide a better quantitative modeling of valuation of information and to uncover its neural correlates. Methods: In behavioral and fMRI experiments, subjects chose whether to play gambles with two possible monetary outcomes. They were endowed with opportunities to buy an additional piece of information about those gambles, with which they could improve their own decisions, by paying monetary cost. Specifically, the two outcomes were perceived as equiprobable initially, and the information revealed the actual probability when purchased. Results: Normatively, subjects should calculate value of information by combining the three quantities at specific weights: 1) the value of the gamble when the information provides good news (the better case scenario), 2) the value of the gamble under bad news (the worse case scenario), and 3) the value of the gamble prior to information. Examining behaviorally elicited subjective value, we found that their relative weights actually deviated from the prediction; the better case scenario was overweighted (in other words, the worse case scenario and the prior were underweighted) compared to the normative model. Next, we conducted representational similarity analysis (RSA) on BOLD signals during presentation of the information. We found that the better case scenario and the normatively predicted value of information were represented in bilateral orbitofrontal cortex (OFC), ventromedial prefrontal cortex, and left temporal cortex. Among them, signals from OFC were better captured by combination of the three quantities (above) at specific weights, which closely matched with those estimated from behavior. Conclusions: Calculation of value of information is biased towards the possibility that the information provides good news. Such calculation may be conducted in lateral OFC.

2-J-33   Removing the curse of dimensionality: a trade-off between adaptability and precision

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Learning from reward feedback is essential for survival but can become very challenging in naturalistic conditions where choice options have many features (e.g. color, shape, texture) and each feature can take many values, resulting in a large number of options whose reward values have to be learned. This challenge is referred to as the "curse of dimensionality," since many value-based learning models (e.g. reinforcement learning) do not scale up as the dimensionality of the environment and thus the number of possible options increase. We hypothesize that humans tackle this problem by adopting models of

the environments that reduce the dimensionality and allow faster learning (model-based approach). We therefore designed a series of experiments to identify factors that influence such model adoption over the slower, but more precise model-free approach, which learns individual values for options. Moreover, we constructed different computational models and tested alternative learning architectures for solving the curse of dimensionality. During these experiments, subjects selected between pairs of options that had different features and would yield reward with different probabilities. We found that when faced with a volatile environment in which reward contingencies changed frequently, most subjects adopted a model-based approach, enabling them to learn quickly. However, when we introduced inconsistencies that prevented reward probabilities for all options to be determined based on their feature values, subjects adopted a model-free approach. The presence of inconsistencies prompted a model-free approach even when we increased the dimensionality of the environment. Finally, we found that these results are compatible with a hierarchical decision-making and learning process where the best sources of information (in alternative models of the environment) were used to make decisions and successively updated according to the reward outcome. Overall, our results reveal that a novel trade-off between adaptability (dealing with the volatility in the environment) and precision (dealing with inconsistencies in the reward structure) determines how humans adopt a model of the environment to reverse the curse of dimensionality.

2-J-34   Neural correlates of subjective preferences and the aesthetic experience of visual art

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Objective We investigated the neural substrates of artistic preference and esthetic experience by using a neuroeconomical paradigm. Existing fMRI literature on art (Zeki) has proposed the ventromedial prefrontal cortex (vmPFC) as a specific substrate of esthetic experience (hypothesis 1, H1), but some studies also report activation of reward-associated circuits (H2). According to the neuroeconomical data, vmPFC may be a generic substrate of subjective preference (H3). Methods Participant chose between artistic paintings characterized by diffuse atmospheric tones. Landscape paintings were chosen from the wide collection by James Ensor (1860-1949), characterized by a style known as "tachism" (no persons or objects shown and paintings were made to give an emotional projection). In each trial, participants were asked to choose the preferred picture displayed on screen (from a set of two at a time) by pressing a button on the side of the chosen alternative. Each trial displayed one of all possible combinations of the 9 paintings available for choices. We ranked the preference score of each picture according to the choices of individual participants, and regressed the trial signal on the difference between these ranks (gradient of preference) and the sum of these ranks by specifying two 'parametric modulators' of the BOLD trial regressors. Results The gradient of preference regressor was associated with activation of the vmPFC, as in neuroeconomical studies of choice. In the sum of scores regressor, this area was not active. Instead, SNpc/VTA and another brainstem area localizable as peducolopontine tegmentum was active. Discussion If H1 is correct, we should observe vmPFC activation in the sum of scores regressor, as viewing two preferred paintings gives a better aesthetic experience than viewing two non-preferred paintings. This was not the case. If H2 is correct, we should observe activation of reward-associated circuits in the sum of scores. This was indeed the case. If H3 is correct, we should observe vmPFC activation in the gradient of preference. This was indeed the case. We conclude that vmPFC is recruited to compute subjective preferences (H3) while aesthetic experience recruits reward-related circuits (H2).

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A peculiarity of this experiment is that subjects can consume the reward during the trial (enjoy the painting). We argue in a separate submission (Motivational processes engaged by levels of reward) that this brainstem activation pattern is a neural correlate of a consummatory form of motivation, distinct from incentive motivation, related to facilitation of sustained attention.

2-J-35   Individuals with ventromedial prefrontal damage have preferences that are more unstable, but fundamentally transitive

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Past studies of individuals with focal damage to the ventromedial cortex (vmPFC) have found them to be inconsistent in preference-based decision-making (Fellows and Farah, 2007; Henri-Bhargava et al., 2012; Camille et al., 2011). However, these studies cannot distinguish between two possible explanations for these inconsistencies: instability of preferences or intransitivity of preference order. For example, individuals with vmPFC damage could have preferences that are intransitive, and stably so (consistently preferring A to B, B to C, and C over A); or transitive but unstable (preferring A over C 60% of the time, therefore sometimes manifesting a C > A error). These patterns can be distinguished using probabilistic models of transitivity, which assess overall structure of preferences over many repetitions. Here we tested 13 individuals with vmPFC damage, 10 lesioned controls with dorsomedial or -lateral damage (DL/DM), and 20 healthy, age and education-matched controls. Individuals made binary choices between rewards in three categories - artwork, chocolate bars, and gambles. Choices between all possible pairs of five unique options in each category were repeated multiple times throughout the experiment, intermingled with choices between all possible pairs of another eleven unique options which were not repeated. Using the non-repeated choices, we replicate previous studies finding that individuals with vmPFC damage make more apparent transitivity errors. This effect was strongest and most selective for the artwork domain, in which individuals with vmPFC damage made more errors relative to both those with DL/DM damage and healthy controls. Crucially, however, not a single individual with vmPFC damage's choices were found to violate probabilistic models of transitivity. These results demonstrate that individuals with vmPFC damage have preferences that are more variable or unstable than controls, perhaps due to noisier momentary value representations, but that their preferences still retain an underlying transitive ordering.

2-J-36   Impact of selective attention on value-based vs perceptual choice

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Research in perceptual decisions choice highlights how attention improves perceptual performance by enhancing early visual processing. Yet it is also known that attention, as measured by relative gaze exposure, correlates highly with value-based preference. Does selective attention improve sensory discrimination or does it just bias choice? We explicate how patterns of eye-gaze reveal differences in information search and processing across perceptual and preferential choice. To compare choice formation across tasks, we used a rapid, experience-based paradigm. We combined features of psychophysical studies of perception by using dynamic sensory with features of subjective preference studies by allowing participants to freely view the presented options. Participants chose between two options represented by circular fields of rapidly changing dots (updated every 50ms) sampled from an underlying distribution. They were told each dot represents a fish on the surface of a pond. We manipulated the type of decision participants made, but held the stimulus constant. Half the

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participants made a preferential choice. They were told that each fish was worth a point and they should decide which pond they wanted to fish from as they would earn points equal to the number of fish in the next sample of fish that surfaced. The other half made a perceptual choice and were told to identify which pond had on average more fish. Participants were shown the number of fish caught after each choice. In the preference frame, this was the next sample of fish that would surface in the chosen pond; and in the perceptual frame, the average number of fish in the chosen pond. The number of fish caught was summed over trials and converted into a monetary bonus. We replicate the result that participants' eye gaze shifts toward the more favored option just before choice; however the effect was stronger in preferential choice. This difference in the biasing effect of attention was present throughout decision. During perceptual choice, participants acquired more information and allocated more time shifting attention between the choice options as compared to the preferential choice. Computational modeling shows that a similar evidence accumulation process is used to integrate the samples of information in both preference and perceptual choice, but even after controlling for information search differences, perceptual choice was associated with more sensitivity to the samples of information and greater response caution than preferential choice. Our results show that although the same general sequential sampling process may be used to make perceptual and preferential choices, how attention is allocated during search differs across tasks, leading to critical differences in choice.

K – Choice & Choice Systems

2-K-37   Towards a Mathematical Description of Similarities and Differences in Physical and Cognitive Effort Discounting

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Physical and cognitive effort constitutes an important factor in everyday decision making. Particularly, it is widely recognized as one of the discounting factors that decreases the subjective value of a reward with an increase of its intensity. To provide a mathematical description of the discounting process by physical and cognitive effort, we tested the performance of multiple discounting models, that were derived from the delay discounting tradition. Data was collected from a total of 114 participants, recruited from the general population. Participants completed a titration choice discounting procedure, that was adapted to test effort discounting. We employed a within-subjects experimental design with two effort conditions (physical and cognitive), three reward magnitudes (small, medium, and large), and five effort intensity levels. Data analysis showed some promising results. Surprisingly, the exponential model performed best, accounting for a substantial proportion of variance in both physical and cognitive effort conditions--significantly more in comparison to the hyperbolic and parabolic models. We therefore propose that, at least to some extent, models derived from delay discounting can indeed be used to describe the process of discounting by physical and cognitive effort.

2-K-38   Mistakes Were Made: The Causal Role of the Superior Frontal Sulcus in Perceptual Choices in a Combined TMS-fMRI Study

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Previous studies in perceptual decision making showed that the left superior frontal sulcus (SFS) is involved in integrating information; however, it is not fully understood how the SFS does it. In this study, we sought to causally show the behavioral and neural effects when we disrupt the SFS in a food choice paradigm. A combined TMS-fMRI experiment with 20 subjects, the experiment was a pre-post design

with perceptual choices as treatment and value-based choices as control. Before placing subjects inside the scanner, they rated food items based on how much the item occupied the black background for perceptual ratings or how much they prefer to consume the food item for value-based ratings. Subjects had to rate each rating twice. After rating, subjects performed binary food choices in the fMRI. They chose which food item occupied a larger portion of the background for perceptual choices while they chose which food item they preferred to consume for value-based choices. We ran 8 runs equally divided into pre- and post-stimulation conditions. Each run had 32 trials of 4 interspersed blocks of perceptual and value-based choices. Before the beginning of the last half, we administered theta-burst stimulation over the left SFS region. Behavioral results indicate that theta-burst stimulation in the left SFS caused a significant decrease in accuracies for perceptual choices, but not for value-based choices and the interaction between treatments and conditions was significant. However, it also decreased response times for both choices, but without having a significant interaction. As a whole, these results indicate that stimulation specifically increased the likelihood for subjects to choose incorrect responses. At the neural level, trial-wise left SFS beta activations are positively correlated with pre-TMS responses in a logit regression for perceptual choices, but negatively with post-TMS responses, indicating a decrease in activation of the left SFS after stimulation. SFS betas are not correlated at all with value-based choices. We also extracted vmPFC betas and showed that it is not correlated with perceptual choices, but with value-based choices. There are also no TMS effects in the vmPFC. Overall, these results show the direct link between stimulation with the behavioral and neurobiological effects on perceptual choices. Hence, we show in this study that theta-burst stimulation causally reduces both choice accuracies and left SFS activations for perceptual choices, but not for value-based choices. This suggests that SFS inhibition interrupts the process of integrating evidence for perpetual choice.

2-K-39   Value-based attentional capture impairs trinary choice

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When choosing between three options, classical economic theory asserts that the choice proportion between two options should not be affected by the value of the third option. However, this claim has recently been challenged by two separate studies (Louie et al., 2013, PNAS; Chau et al., 2014, Nat Neurosci) with contradictory results: Louie and colleagues reported that better third options reduced the choice sensitivity between the other two options and attributed this finding to the normalization of value representations in the brain. Chau and colleagues found the opposite effect and explained it using a biophysically plausible model of decision making. In an attempt to resolve the apparent conflict, we tried to replicate Chau and colleagues' study and analyzed the data in more detail. However, in two behavioral and one eye-tracking experiment with a total of 104 participants, we failed to replicate the choice-improving effect reported in the original study. Instead, better third options reduced decision accuracy. At first glance this appeared to corroborate the normalization account, but this explanation was also incompatible with systematic patterns found in the behavioral and eye-movement data. In particular, we found that i) better third options were chosen more often (even if declared as non-available), but the choice ratio between the other options was unaffected, ii) when people were given sufficient time to make their choices, the decision accuracy was unaffected by the third option, iii) people looked more often at better third options, and the more they did so, the more their decisions were impaired by these options. In summary, our results are best explained by a value-based attentional capture account (cf. Anderson et al., 2011, PNAS): Options with higher values receive more attention, thereby "stealing" the time needed to attend to the other options and to choose accurately. In order to

model the complex interplay of attention and value in trinary choice, we develop a sequential sampling model of decision-making that takes the value-based modulation of attention into account.

2-K-40   The role of GABA and glutamate in anterior cingulate cortex during strategic patch-leaving choices

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Deciding when to leave a depleting resource to exploit an alternative is a fundamental problem for decision makers. The appropriate decision should be based on the accumulated evidence in favour of changing one's policy. Patterns of neural activity in the anterior cingulate cortex (ACC) have been suggested to encode the evidence in favour of abandoning a depleting patch for an alternative. Some evidence suggests that these patterns are governed by a competition via mutual inhibition that is mediated by the local balance between GABAergic inhibition and glutamatergic excitation. We developed a novel patch-leaving task requiring trial-by-trial accumulation of evidence in favour of leaving the current patch. The current patch depleted and the alternative patch replenished according to a decaying Gaussian random walk. In order to move to the alternative patch a traveling cost had to be paid. Subsequent to the patch-leaving decision, a value-guided choice had to be made which was explicitly decorrelated from the patch-leaving decision. We recorded MEG data from thirty-three participants performing the task. Individual levels of GABA and Glutamate in five cortical areas related to key behavioural and computational parameters were acquired using magnetic resonance spectroscopy at 7T. Subjects' choices to abandon the current patch were strongly governed by the accumulated evidence (the values of the current and alternative patch and travel cost). The balance of GABA and glutamate in the ACC was strongly related to the degree to which subjects' patch-leaving choices were governed by switch evidence. Importantly, no such relationship was found with other behavioural parameters such as the overall frequency of switching between patches, reaction times or value-guided decision making. Our data confirm the role of the ACC for patch-leaving choices and indicate a specific role for ACC GABA and glutamate in evidence accumulation during sequential decision making.

2-K-41   How arousal enhances optimal decision making in the human brain

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Objective: Arousal determines an organism's state of responsivity to external stimulation and is a major determinant of how an organism engages with its environment (Pfaff et al., 2012). It has been suggested that the capacity for optimal decision making depends on the current level of arousal (Yerkes and Dodson, 1908). This is because arousal may decrease reaction times while maintaining choice accuracy (Wald and Wolfowitz, 1948), therefore increasing reward rate in a given amount of time (Gold and Shadlen, 2002). However, despite the well-known role of arousal in behaviour, it is currently unknown by which neural mechanism arousal may facilitate optimal decision-making in humans. Methods: We measured pre-stimulus pupil baseline dilation (PBL) as an indicator of arousal level while thirty-one healthy participants alternated between blocks of value-based and perceptual choices that were matched for visual stimulation, task requirements, and motor output. Brain activity was measured concurrently with MRI. We regressed the trial-by-trial reaction time (RT) and accuracy of both choice types on PBL during the decision-phase, while controlling for other choice-relevant variables (e.g., difference between choice alternatives, DV). Results: For both tasks, increased arousal was associated with decreased RTs (both $p < 0.01$) but constant choice accuracy, demonstrating that arousal enhanced

the optimality of decision making. When decomposing the observable behavior (RT and accuracy) into latent decision making parameters using a drift-diffusion model, we found that heightened states of arousal were associated with an increased rate of evidence accumulation for both choice tasks. Corresponding neural effects were found in brain regions where model-predicted trial-wise evidence accumulation correlated with BOLD signals: In the superior frontal sulcus (SFS) during perceptual and the left temporal cortex (LTC) during value-based decisions, DV was represented with a significantly sharper slope during high- vs low-arousal trials. Importantly, the observed DV slope differences in SFS and LTC predicted individual reward rates during perceptual and value-based choices, respectively. Conclusion: Our results show that arousal facilitates optimal decision making by enhancing choice-relevant evidence accumulation in the human brain.

2-K-42   **Revealed Indifference: Using Response Times to Infer Preferences**

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Objective: The revealed preference approach is the dominant method used by economists to infer peoples' preferences. It relies on observing discrete, stochastic choices. However, the choice process also produces response times (RTs), which are continuous and can often be observed even when choice outcomes can not (e.g. voting). We know that there is a relationship between response times and strength-of-preference, so people make slower decisions when they are indifferent. Here we sought to investigate whether it is possible to use this relationship to estimate individual utility functions using RTs alone, without using choice data. Methods: We used three datasets that included choices and RTs of human subjects in three economic choice tasks: a binary dictator game, an intertemporal choice task, and a risky choice task. In the dictator game, subjects made choices between two allocations, which specified their own payoff and an anonymous receiver's payoff; each allocation had a tradeoff between a fair option (more equal division) and a selfish option (with higher payoff to the dictator). In the intertemporal choice task, subjects were choosing between getting $25 right after the experiment or a larger amount (up to $54) at a later date (7 to 200 days). Finally, in the risky choice task, subjects had to choose between a sure amount of money and a 50/50 lottery that included a positive amount and a loss. Results: Consistent with the results in the literature, we found that the longest RTs typically correspond to trials with equal utilities, allowing us to infer preferences by averaging the indifference parameters in these trials. Without using the choice data, we were able to recover individual utility functions from the RTs and predict choices out of sample. In some cases, these predictions were not statistically distinguishable from those based on the choice data themselves. We found that trials with the longest 10-20% of RTs yielded the best results in terms of out of sample prediction. Furthermore, we were able to use long RTs to predict which choices were inconsistent with a subject's utility function and likely to later be reversed, providing evidence against deliberate randomization as a mechanism underlying stochastic choice. Conclusions: These results provide a proof of concept for a novel "method of revealed indifference", which relies solely on the fact that choices near indifference are relatively slow, and thus does not depend on a particular data-generating process. In our settings this method seems to work better than other approaches based on single trials or full RT distributions (Schotter & Trevino 2014; Chabris et. 2009). These findings provide a foundation for including response-time data into economic analysis.

2-K-43   **Naturally nice and controlled: effects of exposure to nature on stress and decision making**

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Exposure to natural environments increases happiness, improves mood, and restores attention. Yet, little research investigates how natural environments influence decision making. Our first aim was to determine whether exposure to nature scenes influences decision making in three tasks: intertemporal choices, risky choices, and dictator games. Participants viewed either images of nature scenes, urban settings, or geometric patterns for five minutes before completing the decision-making tasks. We found that, unlike previous studies, exposure to nature did not influence patience, risk-taking, or cooperation. Our second aim was to test whether stress acts as a mechanism that could mediate the effect of nature on decision making. To test stress as a mechanism, we measured physiological stress levels via electrodermal activity during the decision making tasks. Electrodermal activity did not differ between participants exposed to nature or urban scenes, however. Because electrodermal activity is a general arousal response and not stress specific, we then measured a more specific biomarker of stress: salivary alpha amylase. Exposure to nature scenes reduced baseline alpha amylase levels, maintained this reduction in the face of an external stressor (cold pressor task), and carried over into the decision-making tasks. Thus, we conclude that exposure to nature reduces stress, which could account for previously described effects on decision making. This provides important insights into potential interventions to improve self-control and cooperation.

2-K-44   New flavor of the exploration-exploitation trade-off in contextual multi-armed bandit problems

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Concepts from the field of reinforcement learning (RL) have revolutionized human and animal learning and decision-making. However, applying reinforcement learning algorithms in more realistic multi-dimensional environments is challenging. To battle the curse of dimensionality in such environments the algorithms need to reduce the dimensionality by learning the function between the dimensions and the value of actions. Moreover, exploration-exploitation trade-off acquires a new flavor as explorative choice can be made to learn the function, not necessarily the value of an action. We developed a novel contextual multi-armed bandit (CMAB) task and hypothesized that humans too will rely on learning the structure of the environments to successfully navigate the task and that their their exploration will be guided by the functional knowledge. One thousand four hundred and fifty six subjects participated in five experiments with monetary payoffs. Subject did either a CMAB task where they chose repeatedly between multiple alternatives characterized by two informative features and received outcome feedback on their choices, or a multi-armed bandit (MAB) task where feature information was not presented. Experiments differed in terms of the function governing the relationship between two dimensions and alternative values. To examine the extent of function learning, the CMAB task was followed with an extrapolation test phase where in each trial three new alternatives were shown, generated by the same function. Behavioral analysis showed that CMAB participants performed slightly better than MAB participants. However, inter-individual differences are large and those participants that learn the function better, as judged by the performance in the extrapolation task, perform much better. Access to contextual information can be detrimental as well - benefits are the biggest when functional relationships conform the prior expectations, while they suffer if the relationships are unexpected and prior needs to unlearned. Our examination of choices when switching to new alternatives and choices in the feature space reveal that indeed exploration patterns in the CMAB task are heavily influenced by

functional knowledge. We modeled the behavior computationally with three classes of models - naïve RL models that ignore feature information, RL models that use function learning to learn the structure and Gaussian process based models that also perform active learning. These models balance the exploration-exploitation trade-off differently and Gaussian process based models showed to be the best in explaining the exploration patterns observed in our contextual bandit task.

2-K-45 (Only) remembered choices shape future preferences

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Standard choice theory assumes that decisions result from stable preferences. This position has been challenged by claims that the act of choosing between goods in turn may systematically shape preferences. We tested this assumption in a series of experiments addressing (i) incentive compatibility of choices, and (ii) whether memory of past decisions was a critical boundary condition for choice-induced preference effects. We adopted an experimental sequence in which participants valued snack items before they made binary choices between equally valued items, and subsequently valued the snacks again. An additional control sequence was implemented that assessed changes in valuations attributable to regression to the mean. Experiment 1 and 2 investigated (using within- and between-subjects designs) the role of incentive compatibility by comparing the effect of choice on hypothetical 'liking ratings' for snack foods with willingness-to-pay assessments for both unavailable and available foods. Available items could be purchased after the experiment in an auction. In Experiment 3, it was tested whether choice effects on preferences were dependent on building up a strong memory representation of choice outcomes during decision making. Across all experiments, there was a systematic effect of choices on preferences, but only for incentivised conditions. After choosing between two items, the stated values of the chosen snacks increased, while the values of rejected items decreased. This finding was robust when controlling for regression to the mean effects. In Experiment 3 it was further found that choice-induced preference effects were stronger for items for which the decision outcome (i.e. chosen or rejected) was explicitly remembered after the experiment. For items that were not remembered, effects were not significant. Contrary to standard choice theory, these results imply that preferences evolved predictably as a function of an individual?s choice history. Yet, decision outcomes only became functionally relevant in guiding future preferences if choices and assessment of preferences were incentive compatible; that is, if participants decided between items that could be purchased after the experiment, and their preference was stated as the proportion of money that they were willing to spend on the items. Moreover, strong effects were only observed for remembered choice outcomes. As such, moderating mechanisms of choice-induced preference effects might be linked to self-relevance and explicit learning from past experiences, which is contrary to previous assumptions.

2-K-46 How election results change the recall of our predictions? An fMRI study on the Hindsight Bias of political election

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Hindsight bias (HB) refers to the phenomenon that people often feel that they knew what would happen, all along, even when that was not the case (Fischhoff, 1975). Cognitive factors such as recollection, knowledge updating, and sense making have been proposed to explain for HB. Specifically, outcome information can be automatically integrated in one's memory representation and such an

updated representation is used to make the retrospective biased judgment (Fischoff, 1975; Calvillo, 2013). HB has been documented in various domains (Blanka et al., 2003; Powell, 1988; Sanna & Schwarz, 2003); however, the neural correlates remained poorly understood. In this fMRI study we asked participants to predict the rates of votes obtained by candidates before election, and to recall their prediction after the election by providing them the actual rates of votes obtained by candidates. The results revealed that 88% of participants showed HB in our electoral task, and they showed HB for 38% of the events. The HB was associated with greater activation in the bilateral inferior frontal gyrus (IFG) and medial frontal gyrus that have been found to be relevant in information updating (Sharot et al., 2011). Moreover, participants' HB% positively correlated with the activation intensity of left IFG. In conclusion, our findings provided the evidence in the neural level that HB is associated with the mechanism of knowledge updating. Keywords: hindsight bias, election, knowledge updating, inferior frontal gyrus (IFG), fMRI

2-K-47   An fMRI Study of A Neural Mechanism: A Competitive Certainty and Immediate Reward

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Objective: Choice under uncertainty (Which do you prefer certain 10 euros or uncertain 20 euros?) and Intertemporal Choice (Which do you prefer Today's 10 euros or 20 euros in future?) have elegant standard theories: the von Neumann-Morgenstern utility theory and the expected utility theory respectively. However neither is free from criticism: Allais Paradox for the former and hyperbolic intertemporal preference for the latter. Both criticisms have a common point: certain reward and immediate income are valued more than they are supposed to be by the standard theories. The purpose of this study is to investigate the differences and similarities between decision-making under certainty and immediate reward choice using fMRI. Methods: Twenty-one subjects participated in the study. Here we used functional magnetic resonance imaging (fMRI) to examine brain activation in subjects making. Subjects are repeatedly asked binary-questions (90 questions for each subject) in the fMRI scanner. Three conditions were used in the task: Delay task, Risk task, and Control task. Results: We found that midbrain and inferior frontal gyrus (IFG) were more activated when they chose a certainty and immediate reward. On the other hand, Midbrain, precentral gyrus and Middle temporal gyrus have been found to be related to future and uncertainty reward. Conclusions: Together with other observations, seems to support, or is consistent with at least, a neural mechanism for evaluating certainty reward partially overlapped with immediate one. In addition, some results is shown "self-projection" proposed by Buckner and Carroll (2006) if people imagine future themselves to choose a future reward. Acknowledgements: This work was supported by JSPS KAKENHI Grant Number 26705001.

L - Social Rewards & Social Preferences

2-L-48   Neural mechanisms of promises, and the punishment of broken promises

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Trust is an important social construct, playing a crucial role in almost all human relationships. Though a promise is usually only expressed orally and is non-binding in nature, it typically promotes trust and enhances cooperative partnerships. Conversely, the breach of a promise gives rise to distrust, betrayal, and even punishment, indicating the important role of non-enforceable commitment in social

interactions. However, few studies have examined the neural mechanisms of non-binding communication on trust decisions, and in particular what happens when promises are broken. The present study aimed to investigate: 1) the behavioral effects and neural mechanisms of processing promises during social interactions; and 2) the neural mechanisms of processing broken promises, and the consequent willingness to punish the betrayer. Twenty-nine participants were scanned using 3T fMRI while they played a modified two-stage Trust Game in the role of Investor. On Stage 1 in each round, participants were endowed with 10 tokens and received a message from the Trustee. This message took the form of either a strong promise to repay, a weak promise to repay, or no promise to repay. Participants then decided how many tokens they want to invest in the Trustee. In Stage 2, participants were informed as to whether the Trustee had repaid their investment or not. They were then endowed with another 10 tokens given the opportunity to punish the respective Trustee. The punishment was both effective and costly (each spent token reduced the Trustees amount by 4). Behaviorally, we found that promise messages (M = 6.45, SD = 1.87) greatly enhanced transferred amounts as compared to the no promise control condition (M = 4.31, SD =1.87), F (2, 86) = 13.49, p<.001. Importantly, breach of promise raised Investors' motivation to punish their partner, in terms of both intensified frequency of punishment (F (2, 86) = 3.84, p<.05) and the amount of tokens spent (F (2, 86) = 4.30, p<.05). In terms of neural activation, promise messages positively activated the bilateral temporal parietal junction (TPJ) and ventral medial prefrontal cortex (vmPFC). The contrast between promise and neutral messages is associated with the brain region of vmPFC. More imaging analyses are ongoing. In summary, the present research shows that non-binding promise messages have a demonstrable effect on individuals' trust decision, and the breach of a promise motivates players to punish, even at a personal cost. Our follow-up work is currently examining the neural mechanisms underlying processing of promises, and the punishment of broken promises.

2-L-49   Neural and Computational Basis of Pay-it-Forward Reciprocity: An fMRI Investigation

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Objective: Pay-it-forward (PIF) reciprocity refers to a special kind of human altruism that people help (or harm) a stranger after being helped (or harmed) by someone else. However, little is known about the neural and computational mechanism underlying PIF reciprocity. In the current fMRI study, we adopted a modified dictator game combining with computational modelling to further address these questions. Methods: Fifty healthy participants (pps) were recruited for the fMRI study (31 females; age = 25.2 ± 3.8). They were told that the experiment was about money split. Each round consisted of two stages. In stage 1, each pp received a certain amount of money from a split of 10 Euro by either an anonymous Player A or a computer. Crucially, both Player A and computer could either choose greedy (i.e. giving less than 5 Euro), equal (i.e. giving 5 Euro) or generous (i.e. giving more than 5 Euro) split to participants. Stage 2 came after a jitter fixation. In this stage, each pp was presented two options of money split between him-/herself and an anonymous Player B. The pp was asked to choose one of the two options in 4s. The option that offers a higher (lower) payoff for player B (the pp) was defined as the generous (selfish) choice. A 2(partner: human/computer)-by-3(offer: greedy/equal/generous) within-subject event-related design was adopted. Each condition consisted of 24 trials (i.e. 144 trials in total). At the end of the study, one trial was randomly selected to be realized to all players (except a computer). Mixed-effect linear regression was used to analyze the choice proportion. Based on the inequality-aversion model5, we built 6 models in which the inequality aversion parameters (IAP) varied across conditions and fitted them to each pp's data. Model was compared based on summed BIC scores across

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pps. fMRI data were preprocessed and then analyzed via GLM. Results: Pps chose generous options more often when treated either equally or generously than greedily. The winning model was the one with free IAPs for different offer types. Neurally, in stage 1, dorso-lateral prefrontal cortex showed increased activation when pps received a split from a human partner (vs. computer). Reward- (e.g. ventral striatum) and aversion-relevant (e.g. anterior insula) regions co-varied with different offer type. In stage 2, right temporo-parietal junction (TPJ) and left insula positively modulated the trial-by-trial utility difference during decisions, calculated by the winning model, only when pps were treated by a human partner (vs. computer). Conclusion: Our results suggest that computational mechanism underlying PIF reciprocity was via TPJ and insula.

2-L-50   Neuroendocrinological signatures of social discounting

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Despite the still frequently made assumption that human decision makers are exclusively motivated by their material self-interest, decades of research in the behavioural sciences suggest that individuals are often much less selfish than originally assumed. However, people are not equally altruistic to everyone alike. Recent evidence suggests that the propensity to forego personal benefits in exchange for another person's advantage declines hyperbolically as a function of social distance, i.e., how much a subject cares about her interaction partner. The decrease in generosity as a function of social distance is dubbed social discounting. We have recently shown that the social discount function is affected by psychosocial stress. We found that men tested shortly after stressor onset showed increased generosity towards close but not distant others compared to non-stressed men or men tested 90 minutes after stressor onset. Stress goes along with a particular endocrine response that follows a distinct timeline: immediately after stress, rapid actions by non-genomic cortisol (CORT) and noradrenaline (NA) signalling pathways exert their effects on brain functioning in concert, but later on, delayed corticosteroid actions affect neural processing alone. Here, we asked if the psychosocial stress effects on social discounting were mediated by isolated or combined action of cortisol and/or noradrenaline. To address this question, I report the results of a psychopharmacological manipulation in which healthy participants received placebo, cortisol (hydrocortisone) or yohimbine, a drug that increases noradrenergic stimulation, or combinations thereof, before performing a social discounting task. I discuss the results of this psychopharmacological manipulation on generosity towards socially close and distant others. The findings of our study has implications for our understanding of neuroendocrine effects on social behaviour.

2-L-51   Inequality of Opportunity and Giving behavior

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OBJECTIVES: Economic inequality has become a topic of great importance for economies and societies as it has substantially increased since the decade of 1970 in both Europe and the United States. Importantly, economic inequality brings significant consequences for society, harming an equal distribution of opportunities for education and health achievements for example. The discussion on inequality of opportunities in society has become even more relevant as Europe is currently undergoing a migrant crisis, which according to recent reports highlights the differences in opportunities offered to migrants and their children as compared to citizens. Despite the societal relevance of inequality of opportunities, previous studies have focused almost exclusively on inequalities of outcomes. In light of

the migrant crisis, it is important to understand the consequences an uneven distribution in opportunities might have on individual behavior. In a behavioral study, we aimed to investigate how inequality of opportunities affects prosocial behavior, more specifically giving behavior. METHODS: Distribution in opportunities was manipulated through chances to earn a lottery prize. A 2 Inequality of opportunity level (high vs low) x 2 Probability of winning (high vs low) design was implemented in a between subjects fashion. Participants (N = 247) either played in a low inequality or high inequality condition. In each condition, participants were assigned to either a low or high probability of winning (PW) a lottery. After seeing their PW, as well as the PW of the other player, participants were asked to play a Dictator Game considering they were the winner of the lottery. RESULTS: Results showed a main effect of PW on giving behavior, being transfers to the other player higher when participants had lower opportunities to win the lottery. Importantly, a main effect of the individual's score on the Economic System Justification scale was also found, suggesting that the more participants tend to accept inequalities, the lower the transfers were to the other player. The level of inequality of opportunity (high vs low) did not affect giving behavior. CONCLUSIONS: Overall, results suggest that distribution of opportunities has an impact on giving behavior. Participants who had higher opportunities of obtaining a specific reward showed less generous behavior towards others. Besides contributing to advance the understanding of inequality of opportunities, these results can provide practical insights on public policies aimed at reducing inequality in opportunities.

2-L-52   Lying for the Greater Good: The Role of Executive-Control and Theory-of-Mind Neural Processes on Pro-Social Deception

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Objective: Deceptive behaviors are not always unethical or harmful. In certain situations, they can even benefit the society. Yet, previous neuroeconomics research has mainly focused on the neural processes of voluntary deception for own gain. It is vastly unclear to what extent neural processes related to dishonest gain (such as, executive control and theory of mind, ToM) are modulated by the societal goal of the deception. We particularly interested in the changes in neural activity when there is an opportunity to deceive others for own gain (selfish deception) vs. for the greater good (prosocial deception). Methods: Employing fMRI, we examined neural processes of 31 volunteers during an incentivized coin-guessing task (adapted from Greene and Paxton, 2009). In each trial, participants were asked to predict a coin-flip. Accuracy in their prediction corresponded to monetary inventive for that trial. We employed a 2 (opportunity vs no-opportunity) X 2 (self vs donation) design. Specifically, during the Opportunity trials, participants had the opportunity to engage in dishonest gain by over-reporting their performance, while during the No-Opportunity trials they could not do so. Moreover, during the Self trials, monetary inventive (earned through reported accuracy) would go to the participants themselves, whereas during the Donation trials, monetary inventive would go to a charitable foundation of participants' choice. Results: As expected, having an opportunity to engage in deception for own gain associated with enhanced activation in executive-control (rostral anterior cingulate cortex, rACC, and ventromedial prefrontal cortex, vmPFC) and ToM (temporoparietal junction, TPJ) regions. Having an opportunity to engage in deception for donation, however, only associated with enhanced activation in the ToM (TPJ) region, but not executive-control regions. Moreover, higher frequency of overall deception was associated with activation in executive-control regions during the Opportunity (compared to No-Opportunity) trials. Finally, difference in the frequency of selfish relative to prosocial deception was positively associated with difference in activation in executive-control regions (particularly at the

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bilateral inferior frontal gyri, IFG) between Self-Opportunity vs Donation-Opportunity trials. Conclusion: When deceptive behaviors are for the greater good, people may not necessary engage in high executive-control processes. Higher executive-control processes are particular needed when people's deceptive behaviors are harder to justify (such as, for own gain). ToM processes, however, are necessary for to deceive others regardless of the societal goal.

2-L-53   The Leader or the Subordinate as a social performer? - The impact of hierarchy rank on social conformity in rats

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Social conformity refers to overwriting own preference with someone else's preferences, which is also found in animals. This study investigated social conformity using a two-diet-choice paradigm in which a short period of social interaction between an observer and a demonstrator rat shifted the food preference of the observer towards the diet the demonstrator ate. As previous studies indicated that only 50-60 % of observer rats showed this phenomenon, we aimed to investigate why some individuals show social conformity and others do not. We assumed that individuals who changed their food preference were social performers and those who did not were asocial performers. But what specific determinants influence this? One potential candidate is social hierarchy rank. Animals can be categorized as the leader or the subordinate, depending on their hierarchy rank order. Ecological models of rat behaviour predict that dominance status affects sensitivity to social cues and could, therefore, determine whether a diet preference change towards the demonstrator's preference occurs. To investigate whether hierarchy rank plays a role in determining which individuals show social conformity, we categorized cage mates as leader or subordinate based on a hierarchy test in an open-field arena. During three days of baseline testing, we measured the food preferences of observer rats who could choose between two appetitive food rewards for six hours each day. On day four, each observer rat was allowed to interact in an open-field arena with a demonstrator rat that was fed with the diet contrary to the observer's food preference. Following this 30 minutes interaction period, another preference test was conducted. For leaders, but not for subordinates, we found a substantial decrease in consumption of the previously preferred diet eaten between pre- and post-interaction preference tests. These results support the hypothesis that socially dominant rats are more prone to social conformity than subordinates. We next aimed to characterize the neurobiological determinants of social conformity. As there is growing evidence that the neuromodulator oxytocin influences social behavior in humans as well as in animals, we investigated whether the bioavailability of oxytocin is a potential determinant of social performance as a function of hierarchy rank. More specifically, we hypothesized that social conformity could be regulated by oxytocin manipulations in observer rats categorized based on their hierarchy rank. In support of this hypothesis, we found differential effects of oxytocin-receptor-agonists as well as -antagonist on social conformity of leader and subordinate individuals.

2-L-54   A matter of distance - The effect of oxytocin on cooperative behavior depends on social distance

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Cooperation is an important behavior enriching human society and can be observed across cultures. However, people do not cooperate with everyone to the same degree. Instead, cooperation declines with increasing social distance between individuals (Strombach et al., 2015). Recent evidence indicates a

central role of the hypothalamic neuropeptide oxytocin (OXT) in modulating cooperative behavior (De Dreu & Kret, 2015). However, so far, it is unknown whether and how social distance influences the facilitating effect of oxytocin on cooperation. We hypothesized an interaction between oxytocin and social distance, such that oxytocin enhances cooperation only for close social distances. 132 healthy male subjects (mean age ± std) participated in a double-blind, randomized, parallel-group experiment. Following the administration of a 24-IU nasal dose of either synthetic OXT or placebo, subjects were first asked to name persons for eight different degrees of social distance (ranging from 1-very close person to 100-unknown person) and were subsequently asked to allocate money between themselves and these people of varying social distance. In total, participants made 24 allocation decisions, three for each degree of social distance. Our results show a significant interaction between oxytocin and social distance. This indicates that oxytocin does not have a general enhancing effect on cooperation, but an effect that is modulated by social distance. References: De Dreu, C. K. W., & Kret, M. E. (2015). Oxytocin Conditions Intergroup Relations Through Upregulated In-Group Empathy, Cooperation, Conformity, and Defense. Biological Psychiatry, 1-9. Strombach, T., Weber, B., Hangebrauk, Z., Kenning, P., Karipidis, I. I., Tobler, P. N., & Kalenscher, T. (2015). Social discounting involves modulation of neural value signals by temporoparietal junction. Proceedings of the National Academy of Sciences, 112(5), 1619-1624.

2-L-55   Mapping the motivations for Trust Game reciprocity

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INTRODUCTION A well-functioning society depends heavily on trust and reciprocity. In the Trust Game, a task typically used to examine these processes experimentally, reciprocity is operationalized as the amount of money returned by the Trustee. This behavior has to date been explained by two different models: guilt aversion (the motivation of the Trustee to match the expectations of the Investor) and inequity aversion (the motivation of the Trustee to distribute the money fairly). METHODS We used a novel variant of the Trust Game, the Hidden Multiplier Trust Game (HMTG), to tease apart the impact of these respective motivations. A novel computational model allowed us to estimate both the relative contribution of the two motivations to reciprocate, as well as an individual 'greed' parameter. We scanned 36 participants using 3T fMRI while they played the HMTG in the role of Trustee. Based on this fMRI experiment, we can construct a neurocognitive model of reciprocal decision-making. RESULTS Behavioral results revealed that both guilt aversion and inequity aversion are important for decisions about reciprocity. Participants employed a combination of these two motivations in decision-making, with our computational model allowing for a precise quantification of this mix in each participant. At the neural level, the magnitude of the investment received significantly correlated with activity in the canonical reward and valuation network of the Trustees. Additionally, the neural response to the investment in left inferior temporal gyrus significantly predicted the amount returned by the Trustee in the same trial, suggesting that this area may represent the trust established between the two players. Further, activity in frontoparietal control regions (left dorsolateral prefrontal cortex (dlPFC) and bilateral intraparietal sulcus, amongst others) correlated with the percentage of the investment returned by the Trustee, supporting a 'selfishness override' account of reciprocity. The response in frontal control regions (bilateral dlPFC and dorsal anterior cingulate cortex, amongst others) also covaried with the 'greed' parameter estimated in our model, such that greedier participants exhibited greater control activation than generous participants when making the same decision to reciprocate. CONCLUSION Overall, we present a novel task, allowing for a new computational model and neurocognitive framework that can help elucidate the psychological and neural underpinnings of reciprocity.

A – Emotion & Affect

3-A-1   Sleep Deprivation Alters the Integration of Affect in Subsequent Evaluations

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Previous behavioral research has suggested that people integrate their affective states to subsequently unrelated evaluations (i.e. affect-as-information effects, AAIE) (Schwarz & Clore,1983), and that AAIE influence evaluations in an affect-congruency manner: more favorably evaluations of positive (negative) objects when people are in a positive (negative) affective state (Cohen et al.,2008). In this research, we investigated how the integration of affect on subsequent evaluations could be modified under sleep deprivation (SD). SD has been known to negatively influence cognitive systems that rely on affective inputs. We hypothesized that the integration of affect will be altered under SD. 21 subjects participated in the study. They were instructed that the goal of the study was to investigate their affective reactions to different types of rewards. In each trial they either won or did not win a monetary reward of S$15 as a manipulation of their affective states and then were asked to evaluate their enjoyment of viewing positive, neutral or negative images on a 9-point scale. Subjects completed the task once under rested wakefulness (RW) state and once under SD. In a multilevel regression analysis, though the main effect of reward on reported enjoyment of viewing images was insignificant, we observed that 1) there was a trend of affect-congruency effect on evaluations in RW such that receiving reward increased the evaluation of neutral and positive images and not receiving reward increased the evaluation of negative images; 2) in SD, the pattern was entirely reversed. Critically, this reversed pattern was qualified by a significant negative 3-way interaction between reward, images and RWSD, and a significant 2-way interaction between reward and RWSD. We show the first behavioral evidence that SD alters the congruency of how incidental affect is integrated into subsequent evaluations. For future studies, this finding raises interesting implications for the putative neural mechanism at play: first, there is evidence showing that behavioral AAIE underlie a physiological integration of affect in brain?s valuation region (i.e., vmPFC) which misattributes to subsequent evaluations (Abitbol et al.,2015). fMRI studies have also shown that SD dampens functional connectivity between the limbic regions and mPFC (Yoo et al.,2007), and that value signals in vmPFC are attenuated in SD (Menz et al.,2012). Together, this may suggest that our behavioral finding of altered affect-congruency effect on evaluations could be explained by SD interrupts connectivity between limbic systems and valuation systems that in turn alters the vmPFC signal during evaluation.

3-A-2   Misfortune might be a blessing in disguise: Fairness perception and emotional experience modulate decision making

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Fairness perception and equality during social interaction frequently elicit affective arousal and affect decision making. Incorporating a dictator game with a probabilistic gambling task, this study aims to investigate the impact of negative experience induced by fairness perception on decision making from behavioral, model-fitting, and electrophysiological approaches. Participants were first randomly assigned to one of the "Neutral", "Harsh", and "Kind" groups comprising various asset-allocation scenarios to undertake different levels of perceived fairness. The monetary gain was then taken as the initial asset in a subsequent negatively-rewarded probabilistic gambling task, in which participants were

instructed to keep as much asset as possible. Our behavioral results indicated that participants in the Harsh group exhibited higher levels of negative emotions but retained more game scores than the other two groups. Parameter estimation of a hybrid reinforcement learning model using the Bayesian approach revealed that these participants were more loss-aversive and consistent in making choices. Our data from simultaneously event-related potential recordings further demonstrated that these participants exhibited larger feedback-related negativities to unexpected outcomes in the gambling task, suggesting an enhancement of prediction error signaling. Collectively, our study suggests that negative experience might be a blessing in the modulation of decision making.

3-A-3   Insula gray matter volume reflects individual sensitivity to observed injustice

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Sensitivity to justice is deeply ingrained in the human nature, and known as a major driver of social behaviors. There is solid evidence that experiencing unjust or unfair behavior is related to an enhanced neural response in the insular cortex. However, so far little is known about the neural basis of vicariously perceived injustice. Here we investigate the structural correlate of vicarious injustice experiences, and its potential to explain individual variability in injustice sensitivity. Given that the insula has been related to the neural processing of experienced unfairness, and that this region is known to simulate similar emotional and motivational states in others, we assumed that the individual sensitivity to observed injustice might be related with the gray matter volume of the insular cortex. To test this assumption, subjects imagined and rated scenarios in which others were subjected to injustice (observer subscale of the Justice Sensitivity Scale). In an independent session, we used structural magnetic resonance imaging to assess their gray matter volume. The results showed a significant whole-brain corrected correlation between the individual ratings when imagining unjust treatment of others, and the gray matter volume of the bilateral insular cortex. The larger the gray matter volume of the bilateral insula, the greater the participant's sensitivity to injustice inflicted on others. These results suggest that the insular cortex plays a role in vicariously perceived injustice, and that the gray matter volume of this region can account for individual variability in the sensitivity to injustice experienced by others.

B – Individual & Lifespan Differences

3-B-4   To ask, task or image? Examining the convergent validity of self-report, behavioral, and neural measures of risk taking and associated constructs in younger and older adults

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Ascertaining if common measures of risk taking and associated constructs assess similar or disparate aspects of a complex phenotype has conceptual relevance and is critical for informed study design: a better understanding of whether measurements tap into common or unique aspects of a phenotype facilitates research comparability and consequently integration. This is especially relevant to the study of developmental trajectories for risk taking, and decision making in general. To further the debate, we conducted two studies investigating the convergent validity of self-report, behavioral and neural measures of risk taking and impulsivity, including changes therein across the human adult lifespan. In study 1, 133 young adults completed a battery of behavioral tasks, self-report measures and two fMRI paradigms (mixed gambles, BART). In a second cross-sectional study, 912 individuals between 18 and 90 years of age completed self-report and behavioral measures of risk taking. The potential for latent measurement clusters in our data was investigated via network analyses. Analysis of neural functional

data involved signal extraction from regions identified by conjunction analysis of group-level statistical parametric maps as common to both fMRI paradigms, followed by computation of zero-order correlations between mean local signal and task performance (within and across tasks). In study 1, self-report measures of risk taking clustered, but correlations between self-report and behavioral measures were weak. Risk taking measures were moderately linked with general impulsivity measures, but less so with domain-specific impulsivity (e.g. food intake). Similar patterns, albeit suggestive of stronger within-task correlations as a function of age, were obtained from the lifespan sample. Group activation maps from the two fMRI tasks yielded common and distinct neural functional components sub-serving risk, value and affective processing. At the individual level, local signal was associated with performance, both within and across tasks. Associating performance on one task with activation on the other was realized for neural regions associated with affect rather than valuation. Our findings suggest that across the human lifespan, self-report, behavioral and neural measures tap into common and specific components (e.g. affective and value processing) of a multifaceted risk-taking phenotype. Associations with impulsivity point towards shared variance; we are currently investigating this suggestion for self- and informant-report, behavioral, hormonal and neural measures of risk taking, impulsivity and self-control in a cross-sectional (longitudinal) lifespan sample.

3-B-5   **Older adults rely more on simpler decision strategies than younger adults when trading off exploration and exploitation in complex choice environments**

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Older adults still need to make difficult decisions about their workplace, health, finances, medical care, etc. There are often too many options available to explore all of them, causing the ubiquitous tradeoff between exploration and exploitation. Objectives. Do older adults make such complex tradeoffs in the same way as younger adults do? Previous work shows that older adults often rely more on simpler decision strategies than younger adults. For example, in relatively complex decision tasks, older adults rely less on goal-directed decision strategies and more on habitual decision strategies. Such strategy changes have been associated with age-related changes in cortico-striatal control loop functioning. We investigate age-related shifts in strategy use in the context of exploration-exploitation tradeoffs depending on the complexity of the choice environment. Methods. Younger (N = 19, mean age = 24.31) and older adults (N = 22, mean age = 70.95) were given four and eight option N-armed bandit problems with the numbers of current gambles and average rewards displayed on the gambling machines. N-armed bandit problems represent typical exploration-exploitation trade-offs. We examined how well participants' behavior was accommodated by a range of computational models. These models included a Bayesian updating model using Thompson sampling, a reinforcement learning model using a softmax decision rule, and various simple decision rules. Thompson sampling provides a near-optimal solution that keeps track of uncertainty (tracking mean and variance) beyond simple action values (tracking means only) or only the last choice (no tracking). These models could be reliably recovered from simulated data. Finally, we measured structural connectivity of the cortico-striatal loops using diffusion weighted MRI. Results. Behaviorally, older adults credibly chose the highest-expected-value option 5% less often than younger adults did in both four and eight option environments (Bayesian anova with logit function and broad prior). Computationally, this pattern is less well accommodated by the near-optimal model and better by the model-free reinforcement model. Neurally, we expect to see lower connectivity in the relevant control loop when decisions deviate more from the near-optimal model (pending analysis). Conclusions. Older adults may rely more on simpler decision strategies to respond to the

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exploration-exploitation dilemma. In doing so, older adults take less information into account and are less tuned to the uncertainty associated with the choice options.

D – Consumer Behavior & Marketing

3-D-6   Behavioral and Neural Preference Signals of Architectural Design

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Objective: Market research plays a central role at the early stages of real-life architectural design projects of residential buildings. Multiple early decisions define central features of the final product. Here we study consumer preferences for one feature of the future apartments: the size of the windows. We tested both behaviorally and with neural measures whether people prefer small, medium or large windows in high-rise apartment buildings. Methods: Thirty adult subjects participated in the study. We presented in-door images of 3D modeled apartments to the subjects. The images depicted four different spaces, and each space was presented with small, medium and large windows (4x3 images altogether). The images were presented to the subjects two times in the fMRI scanner. The subjects were asked to evaluate attractiveness of the presented pictures. After the fMRI experiment subjects were reapproached with an internet-survey where they were asked to rate the images with a scale 0-10. Twenty-six subjects evaluated the images. We analyzed the fMRI data using the general linear model, and run repeated measures analysis of variance. Results: Window size influenced behavioral preference ratings of the indoor images (significant main effect, p<.001). The apartments with large windows were found significantly more preferred than the apartments with small or medium sized windows (p<.001) whereas the preference for apartments with medium windows was only marginally preferred over apartments with small windows (p=0.062). When the subjects viewed the apartments with large windows, the fMRI data revealed increased brain activation in the ventral striatum and the medial prefrontal cortex which have previously been associated with subjective preferences. Conclusions: Both the behavioral and neural results indicate that the window size influences the preference for apartments. Our results suggest that neural measures can be utilized for inferring consumer preferences of build environments. Acknowledgements: This study was funded by Tekes (NeuroService-project). Measures were performed at the AMI Centre of the Aalto University.

3-D-7   Modulation of the automatic approach bias towards high caloric food

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Animals and humans approach rewarding stimuli and avoid aversive stimuli by nature. Also stimuli with a greater reward values are approached faster compared to stimuli with smaller reward values, an effect called automatic approach bias. On the other hand, studies have shown that an approach behavior towards a stimulus can increase its reward value. In this study we aim to investigate 1) whether high-caloric food induces an automatic approach bias as compared to low-caloric food and 2) whether an approach-avoidance training can change this approach bias towards high-caloric food. A total of 40 healthy female subjects participated in this study, taking place on three consecutive days. On the first and last day, all participants underwent the same behavioral testing, using an approach-avoidance task (AAT). On the second day, half of the subjects (intervention group) underwent a training in which they avoided high-caloric food and approached low-caloric food. The other half of the subjects (control group) underwent a sham training, in which they equally approached and avoided both high- and low-caloric food. Our results demonstrate that young healthy participants show an automatic approach bias

towards high-caloric food. Strikingly, an avoidance training towards high-caloric food revealed to successfully decrease this bias in the intervention group. These findings reveal the existence of an implicit preference for high-caloric food that can be reduced with a simple training, opening the door to new potential methods for regulating impulsive food-related pathological behaviors.

3-D-8   Does Red Bull give you wings? Placebo effects of commercially available cognitive enhancers on performance motivation

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Placebo effects are a famous example for the power of expectancies on human behavior and judgment. Prior clinical research has suggested that placebo effect is a kind of anticipated reward response boosting, via the recruitment of dopaminergic motivation pathways, the brain?s ability to suppress pain and symptoms of many diseases. Parallel research from consumer psychology has suggested that placebos such as price tags or branding can also color non-aversive perceptions such as consumption utility. Yet, less is known about how a placebo translates into non-aversive behavior. Here we tested whether effects of energy drinks, frequently consumed to enhance performance under pressure, can stem from a placebo effect. We hypothesized that, through marketing actions of the manufacturer and prior experiences of the product, a person forms positive expectations about learning performance that translate into enhanced motivation. We manipulated label and drink in a 2x2 between-subject design that involved two tasks: a cognitive effort task designed to assess performance motivation and a memory task that served as a control task. Our results (88 participants, mean age: 23.6±2.6) revealed a main effect of label on performance motivation ($F(1,86)=11.9$, $p<0.001$), operationalized as the sensitivity to the number of points at stake in a given trial. There was no drink effect, meaning that motivation and performance were similar whether participants were having Red Bull or lemonade. Our results provide evidence for a robust placebo effect of energy drinks that is selective to motivation. This placebo effect could be mediated by dopaminergic pathways that are known to enhance performance motivation in similar effort tasks. It points toward the possibility that positive expectancies can facilitate drug effects by enhancing motivational processes. Such a potential mechanism of placebo effects provides the promise of a powerful tool for a broad range of implementations from the treatment of disease to enhancing quality of life.

E – Risk & Uncertainty

3-E-9   Connecting Prospect and Portfolio Theories through Relative Preference Behavior

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Introduction: Prospect theory by Kahneman & Tversky and portfolio theory by Markowitz are two cornerstone economic theories of decision-making, yet it is not understood how these two frameworks may be related. Prospect theory is represented by a value function that links the objective economic value of gains and losses to their subjective value to an individual. Portfolio theory proposes a variance-mean function that applies the concept of decision utility to describe optimal risk-return relationships. Here, we explore how these two theories may in fact be related by applying the recent framework of relative preference theory (RPT). Methods: We used a "big data" approach in which subjects from five independent studies provided either rating or keypress data indicating their preferences to approach or avoid various categories of pictures or music stimuli. The RPT value function emerges when plotting a subject's preference uncertainty (entropy) against the mean preference intensity for the category. Both

log (H = a log K + b) and simple power-law (H = b K^a) functions provided strong fits to these data. The RPT variance-mean function emerges by plotting the standard deviation of preference intensity against mean preference intensity; this results in a quadratic function in which σ rises to a peak value or "apex" before declining again. Then, we assessed cross-subject correlations among the following metrics: loss aversion, risk aversion, loss resilience (risk aversion assessed for negative preferences), and approach/avoidance offsets of the value function, and approach/avoidance apexes of the variance-mean function. Results: Across five experiments, there were consistently significant positive correlations between the approach offset and approach apex and between the avoidance offset and avoidance apex across subjects (all p < .05 after FDR correction). No other consistently significant correlations were observed between value function-derived and mean-variance function-derived metrics. Conclusions: The observation of consistent positive correlations between the approach and avoidance offsets from the value function and the approach and avoidance apexes from the mean-variance function indicates a possible link between the value and variance-mean functions, suggesting that RPT may offer a means of uniting the economic theories of Kahneman & Tversky and Markowitz. Furthermore, the exclusively positive correlations between these metrics suggests the existence of a feedforward network absent of any negative feedback, possibly explaining the principle of "irrational exuberance" observed in behavioral economics.

3-E-10   Temporal Characterization of Risk Prediction and Error in the Human Brain

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Intro Two critical parameters needed to make effective decisions are the value of a desired event and the uncertainty of its outcome. These two parameters can be modelled as the first two statistical moments of reward probability distributions: expected value (anticipated mean) and variance (risk). Using this mean-variance framework a new reinforcement learning model has been developed to estimate outcome variance [1]. This model specifies a risk prediction (PR) and a risk prediction error (RiPE) signal. In brief, RiPE is the difference between the size (measured as the square) of the prediction error minus PR (the expected squared prediction error, i.e. the variance). Recently, a growing number of studies have shown, in both humans and animals, neural correlates of risk prediction [2, 3, 4] and error [2, 5], as well as risk learning [6]. One crucial aspect that remains to be tested is the temporal dynamics assumed by this model whereby PR and RiPE signals should be updated sequentially, presumably revealing distinct temporal components. Methods To address this problem we recorded EEG data from 64 scalp electrodes whilst participants (N=10) performed a card game [2]. Participants placed a monetary bet on whether the second of two sequentially presented cards would be higher or lower than the first. Crucially, presentation of the first card generated a RiPE followed by a PR signal before outcome revelation. We used single-trial multivariate discriminant analysis [7] locked to presentation of the first card to discriminate Low vs High RiPE and PR values. Results and Conclusions In line with the predictions of the model, our multivariate analysis revealed two temporally distinct EEG components: an early RiPE component peaked, on average, 310ms after the onset of the first card, whereas a late PR component peaked, on average, at 550ms (before second card). Also, capitalising on the trial-by-trial EEG component amplitudes we observed activity that resembled the hypothesised quadratic decomposition of the two signals. To our knowledge this is the first instance of temporal differentiation of PR and RiPE signals in the human brain as predicted by the mean-variance approach [1]. In fact previous studies in humans had employed either stand-alone fMRI [2, 6] or local field potentials modelling only PR [4]. In conclusion, this finding further cement the evidence in favour of a PR and RiPE

signal mediating learning to enable adaptation in rapidly changing uncertain environments. [1] Preuschoff, K. et al. (2007). ANYAS. [2] Preuschoff, K. et al. (2008). J of N. [3] O'Neill, M. et al. (2010). Neuron. [4] Li, Y. et al. (2016). Brain. [5] O'Neill, M. et al. (2013). J of N. [6] d'Acremont M. et al. (2009). Neuroim. [7] Parra et al. (2005). Neuroim.

3-E-11   The neural basis of perceived risk, cognitive constraint, and expected value in temporal instrumental learning

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Objective: In complex value-based decision tasks, people are often averse to ambiguity, potentially reflecting limited representational capacity (e.g., Payzan-LeNestour & Bossaerts, 2011). In temporal instrumental tasks, however, some individuals may prefer uncertain options and recruit rostrolateral prefrontal cortex (Badre et al., 2011). In this study, we applied the StrategiC Exploration/exploitation of Temporal Instrumental Contingencies (SCEPTIC; Dombrovski & Hallquist, NeuroEcon 2016) model to characterize the neural basis of perceived risk, cognitive constraint, and expected value. Methods: Participants were 69 typically developing individuals (52% female; ages 14-30; M = 21.44, SD = 5.14) who completed 8 runs of a reinforcement-based timing task (Moustafa et al., 2008) during an fMRI scan (Siemens Tim Trio 3T; TR = 1.0s, TE = 30ms, 2.3mm isocubic voxels). Runs consisted of fifty trials in which a dot revolved 360° in 4 seconds. Participants pressed a button to obtain a probabilistic reward from a time-varying monotonic contingency. Behavioral data were fit using the SCEPTIC model, and HRF-convolved decision signals were entered in model-based fMRI analyses. fMRI data were analyzed using FILM + FLAME1 software (FSL 5.0.8) with voxel-wise p = .001 and cluster p = .05. Expected value = estimated value of the chosen response time; perceived risk = entropy of the expected value curve; and decay = AUC of value decay for unchosen response times due to cognitive constraint. Results: Choices histories reflected ambiguity-averse value-based decision-making with a cognitive constraint on the maintenance of action values. Perceived risk modulated the frontal eye fields and medial intraparietal sulcus. Value decay was associated with activity in the frontal operculum, DLPFC, lateral IPS, and putamen. Activity in the central orbitofrontal cortex and ventromedial prefrontal cortex scaled parametrically with expected value. Reward prediction errors modulated the ventral striatum, right inferior frontal gyrus (IFG), and medial dorsal thalamus. Conclusions: In a complex temporal instrumental paradigm, we found that neural activity reflected canonical areas involved in value representation and reward prediction errors, as well networks implicated in cognitive control and working memory maintenance. Activity of the frontoparietal network increased in proportion to the perceived risk of choice, which may reflect transient recruitment of cognitive control (Dosenbach et al., 2007) when relative value differences are small. Decay in value representation due to cognitive constraint was represented by a lateral cognitive network, which aligns with the role of DLPFC in modulating working memory capacity in lateral IPS (Edin et al., 2009).

3-E-12   Financial and sensori-motor decisions: Do learning-induced changes in risk-preferences transfer across domains?

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Although, the need to trade-off risk and reward is ubiquitous - from deciding when to cross a busy road, to making investment decisions - the extent to which trade-offs rely on a common mechanism is unclear. Here we borrow an analytical approach from learning paradigms. Using a task favouring tuning

of risk preferences, rather than learning of stimulus-response associations, we trained people to make better decisions in one domain (e.g., sensori-motor) and test the extent to which such learning transfers to the other domain (e.g., financial). In pre-training, participants performed a standard speeded pointing task to learn about their sensori-motor uncertainty. This was followed by a 2AFC choice task, involving high-value/high-risk and low-value/low-risk options (without feedback). For half of the trials, participants were presented with conventional problems (e.g., £10, p=.2, vs £5, p=.4). For the other half, participants relied on their pointing experience to infer risk (i.e., probabilities were replaced by pointing targets with corresponding p(hit)). In training, participants practised either 'pointing' or 'verbal' decision-problems for 6 days. Half of the participants performed the task without feedback (control), and half of the participants received expected value maximization feedback. A post-training session, which involved the same tasks as the pre-training session, followed. Participants who trained with feedback performed significantly better post-training. Moreover, although the improvement was greater in the practised task, participants also improved their performance in the task they did not practice. That is, the training partially transferred across tasks. There were no improvements in the control groups. To characterize the feedback-induced changes in risk preferences, 3-parameter prospect theory models were fit to each data-set. Participants who trained with feedback became more linear in both money and risk, but showed little improvement in their sensitivity to differences in prospects. Training-induced changes in preferences showed partial transfer. Relative to trained domains, untrained domains showed approximately half the change in money, with effects for risk less clear. Our results refute both the identical mechanism hypothesis and strong domain-specificity, and also seem incompatible with the hypothesis that risk preferences are wholly context dependent (as in some sampling models).

3-E-13   Risk Aversion as a Perceptual Distortion

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Objective: The theory of expected utility maximization (EUM) explains risk aversion (preference for a certain payment over a risky payment with the same expected value) as a consequence of concavity of the utility function. This theory, however, counterfactually predicts that choice between two lotteries should be deterministic except in cases of exact indifference, whereas in experiments, the probability of choice varies continuously with the payoffs offered. We present a simple model of the valuation of risky prospects that attributes randomness in choice to imprecision in the subjective representation of offer values, and show that it also predicts apparent risk aversion even in the absence of nonlinear utility. The model is based on neural descriptions of numerical processing in macaques and humans. We test implications of this model with a risky decision-making task involving a series of independent choices. Methods: Subjects (N = 20) made a series of choices between a certain monetary offer, and a lottery offer with a variable binary outcome. Certain (C) offers ranged from $5.50 to $31.40. A range of lottery offers was paired with each unique value of the certain offer. Each lottery presented a 58% chance of winning a particular multiple of C, or $0 otherwise. Each pair of offers was presented in a randomized order. Subjects were instructed to choose the option they preferred. A single trial was chosen at random at the end of the session and actualized for payment. Results: At the population level, subjects in the task exhibited risk aversion in the range of previous laboratory experiments (mean $\alpha = 0.72 \pm 0.02$). As predicted by the proposed model, estimated psychometric functions over different values of the lottery were not significantly different across each of the unique values of C. Individually, 15/20 subjects exhibited this pattern of behavior. Average reaction times exhibit peaks surrounding the estimated intercept values as well as the highest offers across the range of lottery offers. Conclusions: These

preliminary findings suggest that the comparison process between certain and probabilistic offers can be explained by a logarithmic neural "code" for numerosity. This model of value comparison provides an alternative explanation for risk aversion that links the average response bias to the degree of variability in choices across trials, unlike other models of either phenomenon. It also offers an explanation for the "Rabin paradox" for EUM, by explaining why even very small bets that offer better than fair odds will often be rejected, without the same people uniformly rejecting larger bets that involve even modest degrees of risk.

3-E-14   **How the risk-reward relationship shapes decisions under risk and uncertainty**

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Objective: In many natural decision making domains, we observe a negative relationship between the risk and rewards associated with an option. The higher rewards that people desire are simply less likely to occur than smaller rewards. In laboratory tasks investigating risky decision making, by contrast, risks and rewards are typically uncorrelated (Pleskac & Hertwig, 2014). If people are used to exploiting the statistical regularities they typically encounter outside the lab, this may systematically impact their decision-making (e.g. Brunswik, 1953). Methods: We exposed 152 participants to different risk-reward relationships in the lab, using monetary gambles of the form ?p chance of winning x, otherwise nothing?. Between-subjects, risks and rewards were negatively correlated, positively correlated or uncorrelated. Participants either chose between two gambles, or indicated their willingness to sell for single gambles. We measured the influence of the different risk-reward ecologies (1) on a common set of gambles that appeared in each of the three conditions, (2) in an uncertainty task, in which participants were choosing between an uncertain option and a sure thing, (3) an estimation task, in which participants made probability judgments based on reward magnitudes alone and (4) a recognition task. Results: Participants were sensitive to the different risk-reward structures in both studies, notably without any external reinforcement in the encoding phase. In study 2, correlated risk-reward structures led to faster processing of decisions under risk of the same structure. This advantage disappeared in the random condition. In decisions under uncertainty, choices were consistent with them inferring probabilities from payoff magnitudes. The estimation task revealed individual differences in participants? beliefs of either priors and/or the structure they encountered in the lab. In the recognition task, participants rejected gambles that did not fit the majority of gambles during encoding (targets and lures). Conclusions: If the default structure that people encounter in the world is a negative risk-reward relationship, the ecological validity of many laboratory gamble studies might be compromised: Decision makers adapt to different risk-reward structures, and subsequently use them in decisions under risk and uncertainty. They infer (subjective) probabilities when they are not explicitly stated, potentially scale them based on previous experiences, and evaluate single options as drawn from a larger structure.

3-E-15   **Risk and surprise in perceptual and value-based decision making**

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Introduction Most decisions involve uncertainty which leaves the decision maker unable to fully predict the outcome of their actions. Different forms of uncertainty exist (e.g., expected or unexpected, perceptual or value-based) and are known to differentially affect decision making and learning. While reward prediction and reward prediction error have been credibly linked to the striatal dopaminergic

system, the identification and localization of expected uncertainty (e.g, risk) or unexpected uncertainty (e.g., surprise) has proven difficult. Previous pupillometry results suggest that the locus-coeruleus noradrenergic (LC-NE) system may encode surprise. Here we study the neural correlates of perceptual and value-based uncertainty to identify common and distinct neural networks of uncertainty processing with a particular focus on subcortical and brain stem structures. Method Twenty-two subjects performed a financial gambling and a perceptual ambiguity task during functional magnetic resonance imaging (fMRI). The first task is an auditory version of a previously established card game, which varies the probability (and thus the risk) of winning a gamble. The second task uses an "adjustable" Necker cube to vary the (subjective) probability of viewing the cube from above or below. We computed individual psychometric curves for each subject based on their responses. We then computed the subjective perceptual uncertainty for each subject using the same model as in the card game. The resulting subjective probability and risk associated with viewing different versions of the Necker cube are used as regressors in the fMRI analysis. Results Group level analysis shows that risk associated with the gamble as well as with the subjective perception of the Necker cube are reflected in bilateral anterior insula. We further identify activation to surprise in insula, bilateral caudate and the brain stem. The latter falls within the extent of an empirically derived LC atlas. This activation is stronger at the beginning of the experiment (in particular the card game), indicating an adaptation to surprising events. Conclusions The data support the hypothesis that different forms of uncertainty (perceptual or value-based; subjective or objective) are processed by a network that involves anterior insula, striatum and the LC-NE system. The LC-NE system is thought to maintain the exploration-exploitation trade-off, with phasic discharge prompting exploration. LC activation signaling surprise reinforces this theory, as a surprising outcome may prompt an agent to further explore her environment to accumulate evidence and drive down uncertainty.

3-E-16   The role of statistical learning in a probabilistic gambling task: Strategies and the beginner's luck
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In our daily life, we experience continuous fluctuations in risk, to which we have to adapt. The sequential processing of risky choices evokes expectations about outcome contingencies. This mechanism could also involve some aspects of statistical learning, but so far no studies have tested this association. Therefore, in a population-based sample of adults (N = 180), here we aimed to investigate the role of statistical learning in strategical adaptation in the Balloon Analogue Risk Task (BART). Statistical learning was measured by the Alternating Serial Reaction Time (ASRT) task. We identified four strategical clusters based on behavioral markers of the BART: (1) moderate/average risk taking, (2) slow processing, (3) risk-averse, and (4) risk-taker strategies. Importantly, the latter two subgroups with distinctive risk-taking profile showed higher statistical learning in the ASRT task than participants with average risk taking. Moreover, the first five experienced outcomes in the BART generally predicted participants' risky choices later in the task: Early unlucky outcomes led to lower exploration and lower risk-taking behavior. This association was most pronounced in the risk-averse subgroup. Based on the findings we propose that sensitivity to probabilities in our environment contributes to forming strong risk-taking attitudes, however, this contribution can be altered by the initial experience. Our results also highlight the role of statistical learning in gambling habits, which could further contribute to better understand maladaptive risk-taking behavior. In two follow-up experiments with lucky, unlucky, and neutral conditions, we replicated the initial luck effect in the BART task when the prime and the test

phases belonged to the same episode. However, experience in a preceding episode had only limited effect on risk-taking behavior. In conclusion, better statistical learning is associated with distinctive risk-taking profiles; and early experience with outcome probabilities can influence sequential decision-making in ambiguous situations.

3-E-17   The neural correlates of uncertainty in probability updating and risky decision-making
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Our decisions are based on our beliefs about the outcomes associated with our options. These beliefs are shaped by a process of updating based on incoming information. The amount of uncertainty associated with these beliefs depends on the amount of information that was sampled and how that information was processed. Recent theory has proposed broad principles about how these processes might operate, but precise details of its neural implementation remain unclear. Here we propose a novel Bayesian updating model formalizing the process of sampling with free parameters that modulate the strength and weight of incoming information. We hypothesize that individual differences in the free parameters were associated with basic number and ratio sense abilities, and that the uncertainty of the posterior after learning would be reflected in self-reported confidence and bias risk-preferences. We investigated twenty-five male adults (age range: 20-30) with a fixed sampling paradigm (always five samples of blue or red marbles of an urn) and varied the amount of information during sampling (amount of marbles of each sample) during functional magnetic resonance imaging (fMRI). After each sampling phase the subjects were presented with a gamble. Model-derived uncertainty estimate was applied on a trial-by-trial basis in fMRI analyses. Our results show the Bayesian weighting parameter was significantly correlated with an external measurement of ratio sense, and that the uncertainty was positively correlated to self-reported confidence. Finally, in contrast with ambiguity aversion, we show that in decision from experience higher uncertainty of the posterior is associated with increased risk-preference. Based on the imaging analyses we are able to identify distinct neural signatures that are associated with the uncertainty (Shannon entropy) of the posterior, Bayesian surprise and the magnitude of the update (KL-Divergence). As expected, uncertainty during sampling is associated with activity in a wide network of areas (including posterior cingulate, dorsal anterior cingulate and ventral medial prefrontal cortex (VMPFC)). Interestingly, during the decision phase uncertainty was only represented in an overlapping VMPFC region. These results provide evidence that the cognitive mechanisms underlying belief updating in humans can be described well within a, slightly modified, Bayesian framework. Furthermore, they suggest that deviations from optimal Bayes may be calibrated to the quality of earlier representations of numbers and ratios. Furthermore they suggest that the VMPFC may have a specific role in representing uncertainty in relation to decision-making.

3-E-18   Computational substrats for the limits in human probabilistic inference
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Uncertainty is a central feature in many decisions we face. Making decision under uncertainty often requires the organisms to have accurate knowledge about probability distribution over possible outcomes. However, information about probabilities can come from different sources, making source integration a key computational problem. In this study, we investigated how humans combine prior experience and current information about reward probability when making decisions. In particular, we asked how the reliability of these two sources of information affect the weights assigned to them in

probabilistic inference. Method. In a lottery decision task, on each trial, subjects were presented with two visual stimuli - one associated with past experience on rewards (prior knowledge) obtained in a previous session and the other a new and independent piece of sensory evidence for reward probability (likelihood information). In order to maximize rewards, subjects should integrate both sources of information by taking into account the reliability of each source so as to compute the optimal estimates of probability. Results. Twenty-eight subjects participated in the experiment. At the behavioral level, we found that subjects were more sensitive to changes in the reliability of likelihood information than prior knowledge. Such tendency contributed to a unique pattern of suboptimal performance: When prior information was highly reliable, subjects exhibited patterns similar to base-rate neglect - they underweight prior information. In contrast, when prior information was highly variable, subjects achieved near-optimal integration. Using fMRI, we found that brain activity in the central orbital frontal cortex (cOFC) and the anterior insula were positively correlated with the reliability of the prior distribution, while the medial prefrontal cortex (mPFC) represented the reliability of the likelihood function. Furthermore, independent region-of-interest analyses suggested that cOFC not only represented the group average of subjective weight (SW) subjects assigned to likelihood relative to prior information, but also the individual differences in SW. These results indicated that OFC reflects the reliability-dependent asymmetry in information weighting and provided insights into the computational substrates for the limits in human probabilistic inference.

F — Intertemporal Decision-Making & Self-Control

3-F-19   Dynamic quantification of the subjective cost of self-control

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Emerging decision-making research suggests that choosing to forego tempting, but suboptimal, rewards in the service of achieving greater overall outcomes (i.e., exercising self-control) may be intrinsically costly to individuals. These 'control costs' are thought to stem from the limited cognitive resources available to support the cognitive demands of exercising self-control. However, an empirical quantification of these costs in humans has not yet been accomplished. We employ a novel decision-making task driven by economic theory to quantify idiosyncratic self-control costs in healthy individuals that are currently on a diet to lose or maintain weight. Participants first rated a series of food items on level of health, taste and temptation. These subjective ratings allowed us to identify a high and low temptation food for each individual. Participants were asked to remain in the experiment room with the high temptation food for a period of time without eating it in order to acquire a monetary bonus. Critically, before exposure and at regular intervals after exposure, participants reported their willingness to pay (from a $10 endowment) to remove the high tempting good and replace it with the low tempting good, effectively revealing their subjective cost of exercising self-control. Bids were realized using a standard economic auction procedure (Becker-DeGroot-Marschak method) at a fixed low hazard rate. Bidding data revealed that, overall, individuals were willing to pay a monetary cost to eliminate both future and current temptation from their environment. On average, bids to remove the tempting food increased over time, suggesting that the perceived cost of exercising self-control grew the longer participants were exposed to the tempting food. We found that subjective control costs were strongly modulated by how long individuals had successfully maintained their diets. Specifically, a negative correlation emerged between the number of weeks on the diet and average bids across the session. Our results provide novel evidence that self-control costs can be numerically quantified in humans and that these costs increase as exposure to temptation (i.e., self-control duration) increases. These findings may

open new avenues of research investigating how manipulating subjective self-control costs can promote more adaptive decision-making in the presence of rewards.

3-F-20 **The influence of short-term aerobic exercise on food decision-making**

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Introduction: Food decisions are often situations of self-conflict, in that the subjective value of taste and health attributes are in opposition. Previous studies demonstrate that self-control is a limited resource. Various factors impair self-control, such as stress and cognitive load (Maier et al., 2015). It is of interest to unravel potential "self-control-boosters", that is, factors that increase health-promoting decisions. Based on a previous fMRI study that found a positive influence of aerobic exercise on reactivity to high-caloric food cues (Crabtree et al., 2014), we explored the influence of short-term aerobic exercise on self-controlled food decision-making. Methods: 60 healthy and health-conscious subjects participated in two sessions separated by 2 weeks. Sessions included either a 30-minute bout of aerobic exercise, or a light stretching program as a control condition. Directly after the intervention, subjects performed a binary food choice task within the scanner (Hare et al., 2009). Out of 120 choices, we constructed 80 self-conflict trials where the healthier was not the tastier product, based on individual ratings. After the functional MRI, we used MRI-based measurement of abdominal adipose tissue. Finally, we applied a bogus taste test to determine whether choice behavior in the scanner is related to caloric intake. Results: Although aerobic exercise increases calorie expenditure, we find that it does not change behavioral or neural correlates of self-controlled decision-making per se. Similarly, calorie consumption is not altered after a single bout of aerobic exercise. However, we find an interaction between perceived exertion and hunger levels, in that participants that found the exercise strenuous and were not hungry benefitted from the training (i.e., made more self-controlled decisions), while hungry participants that found the exercise strenuous did not benefit from training. This interaction between hunger and exercise was related to the degree that choice values were encoded in the nucleus accumbens. Additionally, we found that people with a higher overall fat mass put less weight on health attributes in their decisions. Last, we find that the overall number of self-control successes in the fMRI choice task is correlated with calorie consumption in the bogus taste test, thereby providing evidence for the external validity of the self-control task. Discussion: We find that self-control can be enhanced by exercise when hunger levels are not excessive. We now investigate the effects of longer-term health-promoting activities in an exercise intervention study.

3-F-21 **Optimizing incentive design for intertemporal choice**

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OBJECTIVE: Individuals are often faced with temptations that can lead them astray from long-term goals. Individual behavior in intertemporal choice is heterogeneous--what tempts one individual does not necessarily tempt another. We leveraged computational models of sequential behavior to design interventions to encourage individuals to make and maintain decisions consistent with long-term goals. METHODS: We formalized delayed-gratification tasks as a Markov decision problem. At each state, a rational agent decided whether to take a small reward sooner or wait for a larger, later reward. To account for variations in human behavior, we incorporated utility discounting as well as the notion of time-variant willpower. This parameterized model was then used to optimize over incentive schedules to maximize adherence to long-term goals. We fit the model to data from an experimental analogue of

the sequential decision task. Amazon Mechanical Turk participants played a game where they repeatedly chose to wait in either a short line with a small payoff or a longer, more frustrating line with a larger payoff. While bonuses incentivized waiting in the longer line, participants were allowed to switch lines at any time. RESULTS: Our model characterized player performance with and without incentives, and the incentives determined by the model yield a significant improvement in performance. ver all simulated incentive schedules, we observed a "finish line" effect, where proximity to the end of the line increased the likelihood of waiting regardless of the agent's trait or state willpower. Further, the model predicted that incentives delivered just after entering the line were most effective in preventing defections to the shorter line (as opposed to those delivered closer to the end of the line). CONCLUSIONS: We developed a computational model for a continuous intertemporal decision making process that was used to optimize incentive design. This model may provide a framework for individualizing incentive structures to encourage goal-directed decision making.

3-F-22   Dissociable Effects of Age and Testosterone on Adolescent Impatience

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Objective: The onset of adolescence is associated with an increase in transgressive behaviors, from juvenile delinquency to substance use and unprotected sex, which are often attributed to increased impulsiveness. This increase is assumed to result from differential maturation of a subcortical affective brain network and a cortical control network. More recently it has been hypothesized that pubertal hormones may specifically modulate the function of the subcortical regions, and increase reward seeking behavior. However, much is still unknown about how pubertal hormones impact brain and behavior. Here we focus on the role of testosterone in impatience in adolescent males. In a previous study, we found dissociable effects of age and pubertal testosterone on impatient behavior on an intertemporal choice task. To gain further insight into these mechanisms, we designed a follow-up study in which we aim to investigate the different effects of age vs. pubertal testosterone on brain structure and function Methods: We tested N=75 male adolescents (ages 10-15) and N=25 male young adults (ages 20-30) on several delay discounting paradigms in and outside the MRI scanner. Here, we assessed both functional and structural neuroimaging sequences. Furthermore, testosterone levels were measured based on two morning saliva samples provided by each participant. We also used the Pubertal Development Scale (PDS) self-report measure to determine pubertal stage. To further quantify the processes on the intertemporal choice task, we fitted a series of discounting models and compared them using Bayesian model comparison techniques. Results: First behavioral results show that puberty is related to increased impatience, whereas age is trending in the opposite direction. Furthermore, adolescents showed less activity in the insula in presence of immediate rewards compared to adults, and insula activity was also related to individual differences in pubertal status. This finding is in line with current models of adolescent brain development, which hypothesize that subcortical affective brain areas are specifically associated with pubertal development, thus making adolescents particularly sensitive to near-term rewards. Conclusion: As a conclusion, our results highlight the importance of studying pubertal development and emphasize the necessity to also integrate measures of pubertal development (and not exclusively age) when trying to understand adolescent impulsivity.

3-F-23   Positive autobiographical memory retrieval effects on temporal discounting: neural mechanisms

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Objective: In intertemporal choice, people generally prefer rewards sooner rather than later (temporal discounting). One way to reduce temporal discounting is to imagine positive future experiences. Given the overlap in the neural circuitry associated with imagining future events and remembering past events, we previously tested whether recalling positive memories also promotes more patient choice, and we found that this was the case. Here we examine the neural mechanisms by which positive memory recall reduces temporal discounting. Methods: On Day 1, participants wrote about positive memories. On Day 2 (~3 days later), they did an intertemporal choice task in the fMRI scanner (N = 35). There were two block types: in 'Memory' blocks, participants mentally simulated the memories that they wrote about on Day 1 before making a series of intertemporal choices (e.g., "$10 today or $15 in 7 days?"). In 'Rest' blocks, they relaxed and attended to their current state before making choices. We fit hyperbolic discount rates separately in the Memory and Rest blocks, and computed the subjective value of each delayed reward. We examined BOLD signal during memory recall compared to rest, and during choices in the memory blocks compared to rest blocks. We also examined neural correlates of delayed reward subjective value. Results: Here we did not replicate the previous study's behavioral finding, but there was a trend suggesting that people were more patient after recalling positive memories compared to after rest (t(36) = 1.66; p = 0.11). During memory recall compared to rest, there was robust activity in regions involved in both episodic memory retrieval and future thinking, including medial prefrontal cortex, posterior cingulate cortex, and medial temporal lobe. Across both memory and control conditions, BOLD signal in ventromedial prefrontal cortex and ventral striatum correlated with the subjective value of delayed rewards. No brain regions correlated with subjective value more in the memory condition relative to control. However, BOLD in the right posterior temporoparietal junction (TPJ) during memory choice trials significantly predicted whether participants would be more likely to choose delayed rewards in memory trials compared to control trials. Conclusions: These preliminary fMRI results suggest that recruitment of a region implicated in perspective-taking and self-processing, right TPJ, may lead to reduced temporal discounting after an episodic memory manipulation. Uncovering the neural mechanisms by which such strategies work will help with developing interventions for increasing patient choice.

G – Computational Modeling

3-G-24   Strategic Exploration/exploitation of Temporal Instrumental Contingencies (SCEPTIC): a reinforcement learning (RL) model with a memory constraint

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Objective: Do people engage in uncertainty-driven exploration -- which may be advantageous but cognitively costly -- to maximize their rewards? This does not seem to be the case when only a few actions are available (Daw etal, 2006; Payzan-LeNestour & Bossaerts, 2011). It has been suggested, however, that people engage in uncertainty-driven exploration when faced with a temporal contingency -- a large continuous action space (Moustafa etal., 2008). To evaluate this hypothesis and to examine the role of memory constraints in exploration/exploitation of temporal contingencies, we propose a new RL model (SCEPTIC), and systematically test its features in simulations and against human behavior. Method: SCEPTIC learns the expected value of responses over a time interval using a realistic temporal basis function (Ludvig etal., 2008). We apply the variational Bayesian approach to evaluate model features including various uncertainty-driven exploration strategies and memory constraints in simulated environments and vis-à-vis behavioral data (N=76) from Cohen & Frank's clock task. TD and

Frank's TC model (Moustafa etal., 2008) served as benchmarks. Results: Unlike TD and TC, which fail to reliably recover all subject-level parameters in simulations (R2>.14 and R2>25, respectively), SCEPTIC recovers them reliably (R2>.93). It also affords the best fit to human behavior (Bayesian omnibus risk [BOR]<10 -43). In simulations, compared to softmax exploration, uncertainty-driven exploration dominates in the initial environment, for which the parameters are optimized. This advantage is lost, however, when models forage in 100 novel environments relying on the same parameter sets. Furthermore, humans avoid uncertain areas of the time interval to a greater extent than dictated by their reward value (BOR<10 -18). Crucially, individuals' foraging trajectories are best explained by a simple memory constraint (BOR<10 -43): if action values are not updated, they decay, erasing the more distant reinforcement history. Discussion: Uncertainty-driven exploration does not confer a robust advantage during foraging because a generally optimal exploration/exploitation tradeoff is unattainable. It is thus not surprising that humans display uncertainty aversion. Memory decay constrains human foraging in a large action space. In this setting, reward prediction error updates, regardless of direction and magnitude, 'refresh' value traces and prevent decay (cf rehearsal on working memory tasks [Barrouillet etal., 2004]). Our results extend earlier findings of working memory constraints on RL (Collins etal. 2013).

3-G-25   How Humans Solve Complex Problems: The Case of the Knapsack Problem

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OBJECTIVE: Life presents us with problems of varying complexity. Yet, complexity is not accounted for in theories of human decision-making. Here we study instances of the knapsack problem (KP), a discrete optimisation problem commonly encountered at all levels of cognition, from attention gating to intellectual discovery. In the KP, the decision-maker has to find the combination of items of given values and weights that maximises total value (utility) of the knapsack subject to a weight constraint [Meloso e.a., 2009]. The KP is computationally challenging ("NP-hard") [Kellerer e.a., 2004], and traditional economic exploration, whereby one spends effort until marginal gain (from effort) equals marginal cost (of effort), and related stochastic exploration principles such as softmax, are inappropriate. The goal of our study was to explore how humans solve KPs. METHODS: Twenty healthy participants attempted to solve eight instances of the knapsack problem, administered on a computer. Instances differed in computational complexity. Participants were offered two attempts per instance. They were rewarded based on the differences in values between the knapsack submitted and the optimal knapsack. To examine participant choices, we used generalised linear mixed models with participant-specific intercepts. RESULTS: Participants solved on average about 1 of 3 problems, which is substantially higher than could be obtained by trial-and-error. We observed significant heterogeneity in failure rates. Earnings were positively correlated with problem difficulty (measured by failure rate). Failure rates where positively related with Sahni-k and several other measures of computational complexity. This relationship was attenuated when value-to-weight ratios were more highly correlated across items. The failure rates did not vary with the number of items in the solution, sequence length (total number of items added/deleted), or time spent on the attempt. The number of incorrect items in the full knapsack chosen first significantly determined eventual failure. Participants' approaches resembled properties of major solution algorithms for the KP but seemed to be adapted to problem difficulty. CONCLUSIONS: Our findings suggest that humans (correctly) do not apply the traditional economic exploration principles that have been the focus of neuroeconomic research to date. Overall, our results enable one to characterise human KP solving in terms of the theory of computation, but taking into account two

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features that humans do not share with Turing machines, namely, computational mistakes, and "ownership" of early decisions. The former improves performance; the latter deteriorates it.

3-G-26   Balancing New Against Old Information: The Role of Surprise in Learning

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Humans and animals rely on previously learned knowledge to guide their behavior. A crucial challenge when collecting new data in uncertain environments is the balance between new and old information. How much should we trust what we have learned in the past and how much should we adjust our model of the world based on newly acquired data? Both humans and animals adaptively adjust the relative contribution of old and newly acquired data on learning and rapidly adapt to changing environments. To capture this behaviour, existing models detect and respond to sudden changes using (absolute) reward prediction errors, risk prediction errors, uncertainty-based jump detection and hierarchical modeling. The nature of the environmental change determines which of these models works best. Here we aim to generalize these approaches by using surprise as a trigger for shifting the balance between old and new information. Inspired by information theoretic approaches we first introduce a confidence-adjusted surprise measure to capture environmental statistics as well as subjective beliefs. We formulate the principle of surprise minimization as a learning strategy and derive a class of learning rules, which obey that principle. We then propose a surprise-minimization learning rule, or SMiLe-rule, which dynamically adjusts the balance between new and old information without making prior assumptions about the temporal statistics in the environment. We apply our proposed method to a dynamic decision making task in a Gaussian environment and demonstrate how surprise and uncertainty interact with each other to make learning in changing environments possible. Finally, we discuss implications of surprise in reinforcement learning and link to existing neurophysiological evidences and behavioral data to verify our hypothesis about surprise and its role in learning/plasticity. Our proposed surprise-modulated belief update algorithm provides a framework to study the behavior of humans and animals encountering surprising events.

3-G-27   Flexible adaptation of reward-guided learning to the correlation structure of choice alternatives

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Learning from trial-and-error has been well characterized at the behavioral, computational and neurobiological levels, and shown to play an important role in human decision-making. However, the extent to which the underlying reinforcement learning process adapts to long-term correlations in the environment remains unclear. While learning rates adapt to the overall volatility of choice-outcome contingencies during reversal learning, do learning rules change depending on the presence or absence of the correlations between choice alternatives? To answer this question, we asked healthy subjects (N = 30) to play a repeated two-armed bandit game where: a) rewards which could be obtained from the two levers were either uncorrelated or anti-correlated over time, and b) rewards from the unchosen lever on each trial were either shown or hidden (complete or partial feedback information), in which case they could only be inferred. This design allowed us to ask two questions. First, do subjects apply the same learning scheme when they have to infer, rather than observe, the reward from the unchosen lever? Second, do subjects adapt this 'fictive' learning process to the correlation between rewards from the two levers? Bayesian model selection revealed that subjects apply different learning schemes in

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complete and partial feedback conditions, and adapt learning rules depending on the presence or absence of reward correlations between levers. When both chosen and unchosen rewards were shown, a learning scheme which tracks the relative preference for one lever over the other outperformed learning schemes using separate value representations of the two levers (exceedance probability pexc > 0.99). The opposite pattern was observed in the partial feedback condition, where a learning scheme which tracks the absolute values of the two levers better accounted for the human data (pexc = 0.99). In this condition, subjects adopted a 'normalization' learning rule by updating the value of the unchosen lever with the negative prediction error for the chosen lever when rewards from the two levers were anti-correlated (pexc=0.88), and a 'regression-to-the-mean' learning rule when rewards were uncorrelated (pexc = 0.89). These results were confirmed by model-free analyses of human choices and transient changes in pupil diameter in response to chosen and unchosen rewards recorded simultaneously. Together, these findings show that human subjects encode the correlation structure of their environment through fictive learning rules which change flexibly as a function of the presence or absence of correlations between choice alternatives.

H – Game Theory & Strategic Interactions

3-H-28   Inferring the Beliefs of Others during Cooperative Decisions

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Theory of Mind and mentalizing capacities are classically examined with the so called "False Belief Task". We transferred this task's basic concept into the realm of social decision making to investigate how people predict other agents' behavior during value guided choices under uncertainty and under conditions favoring cooperative coordination. Two individuals engage in a simple choice task, in which probabilistic outcomes that also depend on the partner's choice have to be learned and cooperative choices are highly rewarded. After periods of successful cooperation, one player's (the Learner's) outcome distribution is reversed, but only the other player (the Teacher) is informed about this reversal. The Learner thus has a false belief about the state of the world. To maximize the reward, the Teacher must track how the Learner's false belief evolves over time and must act to restore a correct belief to the Learner. During each trial, both players make explicit predictions about their partner's choices before making their own. In line with the Learners' false belief, the Teacher initially predicts unchanged behavior for the Learner. However, he/she switches his/her own choice. On the one hand, the Teacher's choice switch assures a maximal possible outcome for both players given the Learner's false belief, while on the other hand, it informs the Learner about the contingency switch. The Learner typically detects the Teacher-signal and then correctly predicts the Teacher's choices. After accumulating enough evidence, the Learner reacts to the new reward distribution and adjusts his/her choice. During reversal trials, the Teacher's reaction times increase, reflecting increased mentalizing when incorporating the Learner's belief into the own decision process. The Teacher accurately predicts the learning curve and matches his/her own choices. The interactive nature of the task and the need to track and incorporate a partner's beliefs into one's own decision making, allow inquiry into mentalizing processes during cooperation in an ecologically valid design.

3-H-29   Of love, sticks and stones: Acute stress differentially affects ingroup love and outgroup hate

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Acute stress was found to affect a variety of cognitive domains in a negative, but also in a positive fashion. In social decision making, recent work has highlighted that stressed people behave more altruistically, and thus invest into social networks - a putative coping strategy called 'tend and befriend'. Yet, such 'tend-and-befriend' tendencies stand in stark contrast to the classic 'fight-or-flight' response to acute stress. The pivoting determinants of this bi-directionality of the stress response remain unknown. We have recently shown that psychosocial stress boosts generosity only towards a delimited inner circle of friends, family and close acquaintances, but not towards socially more distant individuals. Here, we test whether acute stress amplifies affiliative behavior towards members of an in-group, but aggressive behavior towards out-group members. In the current study, we used a natural group design to elicit in-group/out-group sentiments. Six participants who were fans of competing football teams were assigned to two groups according to their team affiliation. They subsequently performed an "intergroup prisoner's dilemma maximizing differences" game (IPD-MD) after being subjected to psychosocial stress. In the game, subjects received an initial endowment that they could either use to maximize their own monetary outcome (egoistic motive), increase the outcome of their in-group members (altruistic in-group love), increase the income of their in-group members while reducing the payoff of the out-group members (parochial altruism), or only reduce the payoff of the out-group (spite). We show differential effects of psychosocial stress on in-group love and out-group hate.

I – Learning & Memory

3-I-30   Route-based Learning and Map-based Planning during Navigation: Contributions of the Reward System

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Objectives: How do people make decisions when navigating through different environments in their daily life? Extensive research on spatial navigation reports that humans use either a route-based or map-based strategy when navigating in novel environment (Iaria et al., 2003; Bohbot et al., 2007). Here, we take an innovative approach combining spatial navigation and reward-based learning to: 1) investigate the relationship of the neural process underlying of model-free vs. model-based learning and route vs. map based navigation; 2) examine brain areas pertaining to computationally relevant signals during navigation. Methods: Twenty nine healthy, right-handed female (21 - 29 years of age) performed a navigation task while undergoing functional magnetic resonance imaging (fMRI). During the encoding phase, subjects had to repeatedly find rewards located in fixed designated rooms promoting a route-based strategy. During retrieval and search phases, we encouraged map-based planning of new routes by asking subjects to find specific rewards. We calculated the proportion of optimal trials to the total number of trials in a respective phase to get an index of a subject's tendency toward map-based or route-based strategy (map/route index). To characterize subject's choices, we fitted several reinforcement learning type algorithms (model-free, model-based, and hybrid models). We then assessed the degree of model-based influence on choices using the fit of the weighting parameter in the hybrid algorithm. Results: We found significant positive correlation ($r = 0.77$, $P < 1E5$) between map/route index and weighting parameter. This strongly suggests that higher reliance of model-based learning was associated with engagement of map-based strategy in navigation. Our results also show that BOLD activity correlated with model-free time series in medial prefrontal cortex (mPFC). In contrast, model-based time series were significantly correlated with BOLD activity in bilateral caudate nucleus and parahippocampal place area. Importantly, we found significant negative correlation ($r = -0.47$, $P <$

0.05) between parameter estimates of model-free values in mPFC and weighting parameter as well as a significant positive correlation (r = 0.41, P < 0.05) between parameter estimates of model-based values in left caudate and weighting parameter. Conclusion: Even during navigation, certain brain areas reflected either model-free or model-based values in proportions matching those that best explained choice behavior. Thus, our findings demonstrate that brain regions relevant for reward-based learning are also involved in the computations required during navigation.

3-I-31   Mixed valuation strategies in the context of predictive gaze cues both facilitate and hamper instrumental avoidance learning

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Objective: Learning to avoid threats through individual trial-and-error learning is costly. Fortunately, social cues, such as others' gaze direction and emotional expressions, can aid us in optimizing learning and decision-making. Here, we investigated how participants adapted their behavior when presented with social cues from informative and non-informative social partners. Methods: 40 participants were recruited. We used a probabilistic (.80/.20 reinforcement) two-choice task split into 12 blocks, each consisting of 12 trials. Electric shocks were used as primary reinforcers. In each block participants encountered one of four social partners (faces). Social partners were either predictive, meaning they always gave gaze cues to the bad option, or random, meaning they gazed at a random option. Partners gave their gaze cues using either neutral or fearful emotional expression, leading to a fully crossed 2x2 within-subjects design. Each participant encountered each partner in 3 blocks, and was given no instruction about the role of the partners in the experiment. Results: We found that participants made more optimal choices in both predictive conditions, regardless of emotional expression, compared to the random conditions, with notably worse performance in the random fearful condition. However, notably, even during the third block, participants were not choosing fully optimally when facing predictive partners. We used a modified Q-learning model to explain the behavioral patterns. In addition to learning the values of choosing the two options, we introduced a third value term, with its own learning rate, capturing each partners predictive gaze value. This gaze value was then added to the gazed at options value prior to entering into the softmax choice function. This model could accurately capture both that participants, in each block, would choose more optimally on early trials in the predictive conditions, but that on later trials there was little difference between the conditions. The model outperformed alternatives that only learnt the values of gaze or the options. Conclusions: Participants were able to learn and differentiate between different partners predictive value to aid their decision making in an aversive instrumental learning task. However, they appeared to utilize a mixed strategy such that they kept track of, and used, the values of individual options which hampered reaching fully optimal performance. This suggests that participants are risk-minimizing with respect to a possibility that partners later change their predictive behavior.

3-I-32   Verbal Descriptions of Others' Ability Corrupt Avoidance Learning from Observing their Behavior

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Observational avoidance learning " attaining information about what to avoid through observing others " can be safer and more efficient than individual learning. Observational information should, however, be used flexibly as a function of the ability of the observed demonstrator, for instance to avoid copying

non-adaptive behavior. Information of a demonstrator's ability can be gained both indirectly through verbal description and more directly by observation of actual behavior. Here, we investigated how the interaction of described and actual ability of the demonstrator influenced behavioral performance during an observational avoidance learning task. Forty-three subjects learned a sequential two-choice task to avoid shocks. They both performed the task themselves and observed two demonstrators that performed the same task. Subjects were divided into two groups that were told that the demonstrators were either high performers (Described-High) or low performers (Described-Low). In fact, in both groups, one demonstrator had a high ability (Actual-High) and the other behaved randomly and thus had a low ability (Actual-Low) to learn. Behavioral data were analyzed using logistic mixed models and reinforcement learning models. As physiological indices of learning, we measured skin conductance responses (SCRs) and pupil dilation. Behavioral data showed that verbal information influenced subjects? performance such that the Described-High group performed better than the Described-Low group. Furthermore, the verbal description of demonstrator ability interacted with the actual ability resulting in worst performance during observation of the Actual-Low demonstrator when correctly described as a low performer. Analyses of pupil dilation and behavioral data suggested that the verbal description of demonstrator ability influenced performance by affecting attention directed towards the observational information. In addition, both pupil dilation and SCRs during observation of the demonstrators? choices provided psychophysiological measures of learning. Verbal description of a demonstrator's learning ability as low corrupts observational avoidance learning. In particular, the verbal description interacts with the actual ability of the demonstrator, so that observational learning is most impaired when the actual ability to learn is low, although the description then is correct. We suggest that this effect is partly due to a decrease in attention.

J – Valuation & Value Systems

3-J-33   **Dopaminergic contributions to declining value learning in old age**

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As cognitive abilities decline in normal aging, the ability to learn about probabilistic rewards and to make optimal decisions is impaired. Previous research has shown reduced processing of reward information in the striatum and prefrontal cortex (PFC) among older persons. Although there is evidence that dopamine (DA) modulates some of these effects, it remains unknown whether age-related DA decline affects neural processing in the striatum, PFC, or both. We wanted to assess neural processing of reward information in the striatum and PFC as well as dopaminergic neuromodulation on the same participants. To this end, we measured D1 receptor density across the whole brain using PET in 30 younger and 30 older adults. We also measured BOLD responses with fMRI while the same participants performed a two-armed bandit task. We confirmed that older adults performed the task less well than younger adults. We also found that reward prediction errors in the nucleus accumbens were incomplete in both age groups, because the expected value component at the time of the outcome was absent on a group level. On an individual level however, the strength of the expected-value signal was related to density of D1 receptors in the orbitofrontal cortex independent of age. By contrast, the strength of the expected-value signal at the time of choice in the ventromedial prefrontal cortex (vmPFC) mediated the observed age effects on choice performance. Both age and D1 receptor density predicted the strength of this expected-value signal in the vmPFC, but their effects could not be dissociated. This pattern suggests that age-related DA decline is associated with reduced value signaling in the vmPFC. Finally, we identified a frontoparietal mechanism related to shifting away from the chosen option, which was not modulated by

age or D1 receptor density, but predicted task performance independent of the value signal in the vmPFC. These results demonstrate that declining value learning in old age depends on impaired neuronal processing in vmPFC possibly related to DA decline.

3-J-34   Influence of others' choice behavior on observational learning
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Objective: When making decisions in an uncertain environment, individuals may learn by observing the choice behavior of others. The goal of this study was to investigate whether the learning rate and exploration/exploitation tradeoff of the person being observed would influence how much the observer would imitate when choosing. We tested the hypothesis that brain regions involved in valuation integrate information from direct experience with information related to how imitating others helps making optimal decisions.
 Methods: We measured brain activity of 30 participants using functional MRI while they made decisions in a repeated two-armed bandit task. The reward probabilities of the two options were changing independently and continuously. In some trials, the participants observed the choice of one of two individuals before making their own choice. The outcomes of the two observees' decisions were not shown. Participants were told that the others had previously chosen in the same environment. Their behavior was actually simulated using a Q-learning algorithm with different learning rates and exploration/exploitation parameters, resulting in one observee switching options more often than the other.
 Results: We found that the type of observee influenced the observer participants both in their ability to choose the best option and in the probability that they would switch options. Preliminary neuroimaging results indicate that the lateral prefrontal cortex was more activated when choosing differently from the observee than when imitating. During the feedback phase, the activations in the striatum and insula were stronger in the observation than the no-observation condition. We tested a model of choice in which a value of imitation was computed and incorporated in a standard Q-learning model. The value of imitation increased with successful imitation and after losing when choosing differently from the observee and was updated using an imitation prediction error. Activity of the striatum was positively modulated both by the reward and the imitation prediction errors.
 Conclusions: These findings suggest that brain areas implicated in decision-making and reward processing keep track of how imitating different persons can help learning more efficiently in an uncertain environment.

3-J-35   Model-based Time Frequency Analysis Reveals A Neural Signature of Context-related Reward Processes
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Contextual demands are dynamic as individuals navigate their environment. Given that one's current state provides information about goal-relevant cues, it is important to optimize behavioural programs and select goals appropriately (O'Reilly et al., 2014). We investigated how this ability is supported by multiple underlying processes. One critical process is the integration of knowledge about the current context with momentary stimulus-driven information (Wantanabe & Sakagami, 2007). To examine this, we examined flexibility in reward processing with a novel monetary task that incorporated a contextual manipulation. Healthy adults (n = 95) were instructed to match one of three shapes to a cue shape while we simultaneously recorded 64-channel EEG data. Upon a successful response, one shape was associated with monetary gain, another shape was associated with the prevention of monetary loss, and

the third was associated with neither gain nor loss. To manipulate context, in one block of trials more monetary reward could potentially be gained than lost whereas in another block the potential outcomes were reversed. Time-frequency analyses on the neural data revealed neural signatures in the beta frequency band for context-dependent cue processing: A sustained cluster of context-appropriate processing in parietal electrodes from 100 - 300 ms post-stimulus at 12.5-15 Hz and two clusters in frontal electrodes (100-200 ms post-stimulus at 15-20 Hz and 200-300ms post-stimulus at 12.5-15 Hz). To explore the constituent processes that comprise context-relevant processing, we employed a variant of the drift diffusion model (DDM) (HDDM; Wiecki et al., 2013), a sequential sample model that decomposes response measurements into computational parameters associated with distinct psychological processes (Voss et al., 2004). Using an out-of-sample approach with the neural data and specifying a DDM bound by gain and loss prevention responses, we hypothesized that contextual differences would be captured in the bias parameter and that the drift rate would be predicted by the neural traces. Using DIC as the metric of model fit, we found that a DDM specified to our hypotheses had a better fit to data than a group of nested baseline models, and that the parietal beta-band signature most strongly predicted the model drift rate. The results demonstrate an interaction between context, stimulus, and brain activity, illustrating the nature of context-relevant reward processing in the brain.

3-J-36   Rapidly Adaptive Hedonic Utility

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We consider a simple model of decision making in which there is a limited capacity to make fine distinctions. We show that there are readily implementable mechanisms by which utility functions adapt in real time. That is, if the distribution of rewards shifts, the perceived utility function reacts rapidly, to maintain optimal use of the limited capacity to discriminate. Such rapid adaptation of utility is analogous to well-known properties of the visual system, and might well be implemented by similar neural circuitry. In the case that all that matters is the probability of error, the mechanism is particularly simple. If the criterion is instead to maximize expected fitness, we find a mechanism that is approximately optimal. Although such adaptive utility functions take an hedonic interpretation of preference seriously, and incorporate large swings in levels, they are at once consistent with conventional economics. That is, although there is the possibility of suboptimal choice, this suboptimality stems only from the limited capacity to make fine distinctions. As this ability improves, utility remains adaptive, but choice becomes fully optimal.

3-J-37   Choosing between human values and food: the Pavlovian substrates of intrinsic preferences

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Objective The notion of 'subjective value' plays a unifying role in the theory of choice. We used a procedure developed in functional neuroimaging studies of consumer choice to identify the neural substrates activated by choosing between values that, when put into practice, can give meaning to one's life, such as achievement, community, tradition, or religion, and are unrelated to material needs or financial security (Schnell 2011). Our aim was to identify which, among the known substrates of different systems to compute subjective preferences (executive, goal-directed, and Pavlovian) was activated by choosing between intrinsic values. Since a virtuous life requires the capacity to sustain long-

term goals, as opposed to short-term hedonic pursuits, a virtuous utilitarian view leads to the prediction that executive or goal-directed substrates would be active. Methods N=18 young healthy individuals were scanned in two runs. In the first run participants chose between one of two common values according to their importance in their lives. All values were presented pairwise from the set in each trial to pick a choice. In the second they chose between snacks, shown similarly. To elicit the neural substrate of subjective preference, we computed for each item the number of times it was preferred, and computed the difference of these scores for the two items presented at each trial. This difference value was used as a 'parametric modulator' of the BOLD regressor modeling the trials. Results Instead of the neural substrates usually associated with choice between consumer goods (orbitofrontal cortex) or controlled choice (dorsolateral prefrontal cortex), we found that choosing between intrinsic values activated the amygdala, a limbic system structure which presides over assignment of values to stimuli according to immediate affective experience and their association with rewards. In contrast, choice between snacks activated the orbitofrontal cortex as reported in the literature. Conclusion The amygdala is viewed as the substrate of 'Pavlovian' preferences in animals, and it has not been found to be activated in direct association with subjective preferences in man. This suggests that to make choices among intrinsic values, humans use the affective network that animals often use. These results are consistent with views arguing for the existential nature of values that give meaning to one's life here and now, in contrast to maximizing long-term utility, and with the intuition that some fundamental choices in one's life are not made through consideration of secondary aims.

K – Choice & Choice Systems

3-K-38   Examining the role of memory retrieval in value-based decisions in humans

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Objective: The speed and accuracy of many decisions conform to regularities of bounded evidence accumulation. Such models have proven successful for perceptual decisions made from dynamic sensory input, where integration of independent samples of evidence is normative. However, the same framework applies to economic decisions that do not implicate integration. Here we test the hypothesis that the sequential character of such tasks involves the retrieval of evidence from memory. Methods: Subjects were scanned with fMRI while performing a value-based decision task, and a perceptual decision task for comparison. The value-based decision task required subjects to make a series of choices between two foods that varied in subjective value ($\Delta V = V_i - V_j$) as assessed prior to scanning. The perceptual task required subjects to discriminate the predominant color in a stochastic random dot display comprised of yellow and blue dots. Difficulty was controlled by the probability that a dot color was yellow or blue and this "color coherence" was chosen randomly on each trial. The ΔV (for value decision task) and color coherence (for the perceptual decision task) were entered as modulated regressors in the imaging analysis and we compared the magnitude of the effects of ΔV and color coherence on BOLD activity. Results: Subjects chose the higher-value food more often and their reaction times decreased as a function of $|\Delta V|$. Similarly, subjects accurately indicated the predominant color in the color dots display more often and their reaction time decreased as a function of the color difficulty. Thus, behavior indicated a good match between the value-based and perceptual decision tasks. FMRI data revealed that the two kinds of decisions, when evaluated separately, were associated with activity in distinct brain regions. Specifically, for value-based decisions, modulation of whole-brain BOLD by $|\Delta V|$ revealed activation in cingulate cortex. By contrast, modulation of whole-brain BOLD by color coherence during perceptual decisions was associated with BOLD activity in lateral parietal cortex.

Interestingly, a direct contrast of the two tasks revealed greater BOLD activity in an ROI in the hippocampus, a region known for its role in memory retrieval. This result indicates that the relationship between ΔV and BOLD in the hippocampus during food choice was stronger than the relationship between color coherence and BOLD during perceptual decisions. Conclusions: Value-based decisions were associated with greater hippocampal activity, supporting the hypothesis that memory-related brain regions contribute more to value-based than perceptual decisions.

3-K-39   Pupil dilation reveals latent decision processes in value-based choice

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Objective: Although it is essential to understand how people make decisions, we still do not fully understand the latent evidence accumulation process in simple value-based decision-making. Prior research has shown that eye movements influence the choice process by boosting the evidence for the fixated item. Other research has demonstrated links between pupil dilation and information processing. In particular, it has been argued that pupil dilation may reflect the decision threshold in the drift-diffusion model (DDM). Here, we test this hypothesis and more generally investigate the relationship between pupil dilation and simple value-based decision-making. Method: A total of 44 undergraduate students from The Ohio State University participated in the experiment. Each session consisted of two stages. First, subjects rated 139 snack foods from -10 to +10 based on how much they would like to eat each item. In the second stage, subjects made 200 incentivized binary choices between different food items. During both stages, subjects' eye movements and pupil dilation were monitored using an eye-tracker. Crucially, all the food images used in the experiment were made isoluminant to avoid light reflex effects on pupil dilation. Results: Consistent with prior research, we found that subjects chose in line with their ratings but were also biased toward the last item they looked at. This again confirmed that attention biases choices. As for the pupillometry results, subjects' pupil size during the decision was negatively correlated with reaction time (RT) while post-decision pupil size was positively correlated with RT. On the other hand, neither of these pupil measures was correlated with choice accuracy. Further analysis revealed that pupil dilation influenced RT through interactions with value difference. Specifically, more pupil dilation dampened the effect of value difference on RT. Conclusions: Our preliminary results suggest that pupil dilation plays an important role in the computation and comparison of value in simple choice. Pupil dilation appears to influence both RTs and the effect of visual attention on choice. Drift-diffusion modeling is in progress to better understand these effects.

3-K-40   Neural mechanisms of choice-induced preference change: EEG study

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Objective: According to cognitive dissonance (CD) theory (Festinger, 1957), when a person has to select between two items that are equally attractive, the mere act of choosing one item induces a preference change. Therefore, the chosen item is evaluated more positively and the rejected item more negatively - this is so called a post-decisional re-evaluation of the alternatives. Recent neuroimaging studies suggested a critical role of the medial prefrontal cortex (mPFC) in postdecisional spreading of alternatives (see Izuma 2013, for a review). Here, we used electroencephalography (EEG) to further investigate the role of the mPFC in CD. Methods: During an EEG session 45 right-handed hungry subjects performed a modified version of the free-choice paradigm (Izuma at al., 2010), in which subjects were initially asked to rate their preference for food items. Next, subjects made choices between pairs of

foods which varied systematically so that choices were sometimes made between two equally preferred foods (Self-Difficult trials), and other times between a highly preferred food and an undesirable food (Self-Easy trial). Next, subjects were asked to rate the original set of food items again to detect post-decisional spreading of preferences. Subjects also participated in two control conditions (Computer trials, Post-ex choices). Besides, participants underwent the Eriksen Flanker task. Results: Our behavioral result clearly demonstrated the post-decisional spreading of alternatives, i.e. items that were rejected during Self-Difficult trials were rated significantly more negatively than items rejected during Self-Easy trials. Importantly, event-related potentials (ERPs) and source localization analysis showed a stronger negative fronto-central ERP in Self-Difficult trials, similar to classic error-related negativity (ERN) component recorded during the Eriksen Flanker task. Additionally, time-frequency analysis demonstrated a stronger enhancement of occipital theta activity and stronger alpha suppression during Self-Difficult trails than during Self-Easy trials. Conclusion: ERN has been previously associated with incorrect responses and general performance monitoring mechanism (Young at al. 2004). Our results showed a similarity between CD-related ERP and ERN. Source analysis demonstrated that both CD-related ERP and ERN are generated within the mPFC. Altogether, our results strongly suggest that CD is reflected in the activity of the mPFC as a part of the general performance-monitoring circuitry.

3-K-41   Easy access, easy choice? How attitude accessibility and certainty influence the choice process

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Objective: While attention is integral to decision-making, it is unclear what factors draw attention and thus influence the choices we make. In the attitudes literature, two prominent characteristics of attitudes include accessibility and certainty. Attitudes are opinions or ratings of an item or argument and the ease with which an attitude is recalled is its accessibility. The confidence with which an attitude is stated is its certainty. It is unclear how attitude accessibility and certainty influence attention and choice during value-based decision-making. The attitudes literature predicts that higher accessibility items items should draw more attention, while the perceptual decision making literature suggests that more attention may be aimed at less certain items. Here we aimed to test these hypotheses using eye-tracking. Methods: 36 students from The Ohio State University (OSU) participated in an eye-tracking study on food choice. To measure accessibility, participants first completed a yes/no task where they were asked if they would like to eat a single presented food item. Shorter response times (RT) on this task are indicators of higher accessibility. Participants then completed a rating task to measure their attitudes. Only "yes" items appeared in this task and so participants rated these items on a scale from 1 to 10. After rating each item, participants gave confidence ratings on a scale from 1 to 7 in order to assess certainty. They then made 200 incentivized binary food choices. Results: Participants looked more at lower accessibility items, both in terms of number of fixations and total fixation time. However, subjects were still more likely to choose higher accessibility items. Additionally, subjects marginally chose more in-line with their ratings when both items were higher accessibility. In contrast, while participants did have more fixations on less certain items, this did not translate into more total fixation time on those items. There was seemingly no effect of certainty on choice, although when controlling for the ratings and fixation durations, there was a small marginal effect of choosing the more certain item. Conclusions: These results suggest that attitude accessibility plays a more important role than attitude certainty in value-based decision-making. This demonstrates that attitude certainty and accessibility are separable constructs and that each affect attention and choice in different ways.

Moreover, these results indicate that controlling for attitude accessibility is important when accounting for the effects of overt attention on choice.

3-K-42   **Methodological investigation of economic consistency and its neural correlates**

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Objective: Two different methodologies are used in laboratory experiments to provide individual level data on inconsistency of choices. In the Verbal methodology, subjects are asked to complete a sentence that describes their preferred bundle (Andreoni and Miller, 2002). The Graphical methodology requires subjects to choose their preferred bundle from a budget line that is visually presented and describes the set of feasible alternatives (Fisman et Al., 2007). The results provided by these methodologies are very different. First, the percentage of consistent subjects in the verbal methodology is significantly higher than in the graphical methodology. Second, the inconsistency measures appear to be much higher in the verbal methodology compared to the graphical methodology. In the present study we attempt to reconcile these results, and investigate different aspects of the experimental design. The graphical methodology will later be used in a neuroimaging experiment to examine the neural correlates of inconsistency. Methods: 142 adults completed an incentive-compatible behavioral task, in the context of other-regarding preferences. In each decision problem, a subject was given a randomly picked endowment and was asked to allocate it between herself and an anonymous partner. Each token that she allocated to herself was multiplied by α, while every token she allocated to her partner was multiplied by β. Each subject was confronted either with the verbal or with the graphical methodology. Irrespective of the methodology, subjects were randomly assigned with a number of trials and with an upper bound of α/β. Results: Subjects presented heterogeneity in their other-regarding preferences, which varied from selfishness, egalitarianism and altruism. The average tokens amount allocated to the anonymous partner was significantly lower in the graphical methodology. A multiple regression analysis revealed that the methodological framing and the α/β span affected inconsistency levels, as measured by the Afriat Index. The number of trials did not seem to affect inconsistency. Conclusions: We found that the experimental design influenced subjects' economic consistency and preferences. Therefore, methodological parameters, such as framing and α/β span, affect the magnitude of inconsistency and rational behavior. In an ongoing work (joint with Itay Saporta), we are examining the neural correlates of inconsistency. We aim to identify brain regions correlated with the intensity of deviations from consistency. This may be the first step in isolating the neural basis of consistency.

3-K-43   **Is there "value" in preference?**

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It is generally believed that choices between alternative options are based on the subjective value associated with these alternatives. In this framework, choice preference in favor of one alternative over the other reflects a difference in subjective values. Here we challenge this framework and show theoretically and experimentally how preference emerges without value. Theoretically, we studied choice preference in decision-making networks by considering the dynamics of a standard decision-making network model composed of two large populations of spiking neurons that compete via lateral inhibition. We demonstrate using numerical and analytical methods that substantial response bias

naturally emerges from the microscopic dynamics of the network. This happens even in symmetric settings, in which the two competing populations are statistically identical and receive identical input. We show that the reason for this bias is that the degree of spatial heterogeneities in the network architecture (quenched disorder) and stochasticity of neuronal activity (fast noise) identically scale with the size of the network. As a result, we predict that the distribution of response biases would be wide, even in a symmetric decision-making task. Experimentally, we studied choice behavior of human participants in two experiments, in which the "values" associated with the two alternative actions are equal. In the first experiment, we measured the response bias of participants in a symmetrical version of the bisection task and found that the distribution of response biases across the population of participants is substantially and significantly wider than expected by chance, as predicted by our theory. In the second task, participants repeatedly chose the order of two sequentially executed motor plans and we measured their order preference. Again, we found that despite the task being temporally symmetric, the distribution of order-preference across the population of participants was wide. We conclude that consistent choice preference, even in symmetrical settings, is a natural consequence of the dynamics of competing neural networks and does not require any additional assumptions about a valuation system.

3-K-44   Individual differences in risk sensitivity and model-free learning predict foraging decisions

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Many decisions we make are akin to patch foraging, in which we must decide between a current, known option (patch) and a future, unknown option--this asymmetry requires us to somehow infer the value of future alternatives. Optimal foraging theory provides a solution to this class of decisions, which has long been studied in behavioral ecology: leave the current patch when its instantaneous reward rate falls below the average reward rate of the environment (that is, use information about the environment to infer the value of future prospects). Across species, animals (including humans) consistently show a bias toward staying at individual patches longer than is optimal, despite adaptively adjusting their behavior to changes in the reward statistics of the environment. We hypothesized that some of this bias toward overexploitation could be explained in terms of risk aversion and model-free reinforcement learning (RL). Changing an agent's objective function to account for diminishing marginal utility (risk aversion) would prescribe longer optimal staying times, unmasking optimal behavior that, under the assumption of a linear utility function, would otherwise appear as overexploitation. Additionally, forming stronger stimulus-response associations between stay decisions and the rewards they immediately reap could account for a bias to stay at individual patches longer. This stay bias, if due to behavioral sensitivity to reward, might be revealed through a greater reliance on model-free RL. To test this hypothesis, human subjects (N=408) completed three decision tasks in a randomly assigned order on Amazon's Mechanical Turk. We independently estimated subjects' risk sensitivity (as measured by the power to which absolute values of prospects were raised) from behavior on a gambling task and their model-free learning (as measured by a propensity to repeat previously rewarded actions) from behavior on a sequential RL task. We then used these estimates across subjects to predict behavior on a virtual patch-foraging task. As hypothesized, we found that risk aversion ($\beta\_rho = 0.66$, $p < 0.05$) and model-free learning ($\beta\_MF = -0.49$, $p < 0.001$) independently predicted overexploitation, or staying at patches longer than is optimal. Furthermore, when accounting for these two effects, the group-level index of overexploitation was no longer statistically significant ($\beta\_intercept = 0.11$, $p > 0.30$). These results bear

implications not only for understanding individual differences in foraging decisions, further illuminating how such decisions might be constructed, but also for understanding possible shared features or links among ostensibly distinct classes of decision-making.

3-K-45   Option representation affects decision processing times in a dietary choice task
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When making decisions, the available options can often take a variety of forms. While pondering what meal to order at a cafeteria, one might encounter the word "spaghetti" written on a menu, a picture of spaghetti on a daily specials board, or a steaming tray of spaghetti as it is ready to be served to hungry patrons. Although choosing "spaghetti" in any of these forms will lead to the same outcome, it is unclear whether the different representations of options in a choice set affect decision processes. To investigate the effects of option representation, participants (n = 55) made binary choices between foods presented as either word-word, image-image, or word-image pairs. Prior to making these choices, individuals rated each food for healthfulness, tastiness, and liking, thereby familiarizing them with both word and image representations. Additionally, health or taste primes were presented in the experiment instructions to manipulate goal states in a between-subjects design, and eye movements were recorded to examine information processing during the decision period. The results demonstrate a significant effect of option representation, whereby response times were fastest for image-image pairs and slowest for word-word pairs (F = 170.16, p < 0.0001). There was no main effect of prime on response time, suggesting that health and taste goals do not differentially affect decision durations. Hierarchical Drift Diffusion Modeling (HDDM) was used to explore which components of the decision making process were affected by the option representations. Independent HDDMs were created that varied either drift rate, drift rate noise, or non-decision times according to the representation condition. Model comparison results showed that behavior was best captured when the non-decision time parameter was allowed to vary according to the option representation condition. This suggests that word-form representations of options require the longest non-decision processing times, despite a relative paucity of visual complexity. Further analyses will explore whether information acquisition was also affected by the representation of the options by examining eye movements during the decision period.

3-K-47   Examining the counterfactual thinking of the abandoned option on choice conflict and satisfaction
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Objective: This research aims to explore cognitive and affective aspects of choice. When people evaluate and compare given options to figure one's preference out, decision process is influenced by the composition of options. Here with three types of choice set (e.g. values of choice options; High-High, High-Low or Low-Low valued pair), we expected that choice sets would vary in how much they elicit cognitive conflict and positive feeling. The focus of target (e.g. which to be chosen; Goal vs. No-Goal) was additionally examined and its influence on choice satisfaction will be discussed. Methods: Sixteen adult participants conducted modified Becker-Degroot-Marschak auction task during fMRI scanning. Three types of choice set were presented in a random order and participants chose one of two products to get it later. In half of trials, what to be chosen was the more-preferred option (e.g. Goal) and it was the less-preferred option (e.g. No-Goal) in the other half trials. After scanning participants rated how much each choice set had elicited cognitive conflict and positive feeling of satisfaction and reported how

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much they would like to change one's original decision for each choice set. Parametric modulation analysis was conducted to identify brain regions associated with choice conflict and choice satisfaction. Results: Participants reported higher cognitive conflict and higher positive feeling during High-High condition rather than Low-Low condition. High-Low pairs resulted in the lowest cognitive conflict and the shortest reaction time to decide. The degree of cognitive conflict during decision predicted subsequent reversals of choices. Activations in superior medial prefrontal cortex and supplementary motor area were modulated by cognitive conflict during decision and predicted subsequent reversals of choices together with mid cingulate cortex and insula activations. However, positive feeling of High-Low condition had a similar level to that of High-High condition and was higher than that of Low-Low condition. Activation in nucleus accumbens was modulated by positive feeling from choice sets. Positive feeling was higher when participants chose a goal option than when they chose a no-goal option only within High-High pair condition and anterior cingulate cortex was activated in that contrast. Conclusions: Choice conflict and choice satisfaction, concurrently experienced during decision process, could be dissociated by compositions of choice set. Results replicated previous researches and newly showed lower choice satisfaction as participants focused on the abandoned option of which value was as high as the preferred option.

L - Social Rewards & Social Preferences

3-L-47   Neural substrates of group-based hierarchy and inequity preferences

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Objective: Social dominance orientation (SDO) is a preference for group-based hierarchy and unequal distribution of positive social rewards between dominant and subordinate social groups. Group-based experiments have shown that individuals with high SDO act to maximize the relative payoff difference between their own and other groups, suggesting an effect of group identity on group-based inequity. It remains unclear whether SDO generated inequity is the result of group competitive interactions or of individual preferences for inequity. Here we demonstrate a relationship between SDO and prosociality in anonymous social interactions, and provide evidence that SDO is associated with the structure of DLPFC, a brain region involved in deliberative control. Methods: We acquired brain structure and behavior of 470 participants. SDO was measured with the SDO questionnaire. Social Value Orientation (SVO), a personality measure of individual preference for equity, was assessed with a task of reward distribution between self and others. Subjects played anonymously the Dictator Game (DG, dictator role), Ultimatum Game (UG, proposer role) and Trust Game (TG, trustee role), and responded personality questionnaires of Machiavellianism, empathy, social mindfulness, trust attitude, and F-scale. Results: SDO negatively correlated with SVO. In the SVO task, participants with high-SDO gave themselves the larger reward and those with low-SDO made more equal reward distribution. SDO negatively correlated with reward transfer size in the DG and TG. The UG-DG transfer difference, considered a measure of strategic social behavior, had a marginal positive correlation with SDO. The relationship between SDO and behavior in the DG, UG, and TG disappeared after controlling for SVO. The VBM analysis revealed a positive correlation between SDO and volumes of the DLPFC, VLPFC, and cerebellum. Among the personality measures, only social mindfulness negatively correlated with DLPFC and VLPFC volumes. Conclusions: The behavioral results show a strong relationship between SDO and individual inequity preferences in the absence of group competition. SDO was also related with self-interested decisions in the DG and TG. The strategic social behavior suggests that inequity generated by

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SDO is not indiscriminate. The positive relationship between SDO and the volume of the DLPFC suggests that SDO and related self-interested and inequity generating decisions are controlled by deliberative processes.

3-L-48   Reactions to violations of fairness: Behavioral and neural evidence of of costly punishment

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Objective: We investigate whether people are willing to spend resources to counteract unfairness, both when they are victims and also when they witness injustice towards others, and, if so, whether they prefer to punish the offender or compensate the victim. Methods: Participants (N=38) played the Justice Game while undergoing fMRI. All players started with an endowment of 200 monetary units (MUs). In one condition (First Party - FP), participants faced an opponent (A) that could take MUs from them; in a second condition (Third-Party - TP), they observed two players, one of whom (A) could take from the other (B). Participants then decided to either not intervene, or spend their own endowment to change the payoffs. In FP condition, they spend in order to reduce A's MUs; in TP, they spend either to reduce A's MUs or to increase B's MUs. The punishment (compensation) ratio is 1:3, and participants can only spend; they cannot increase their own MUs. All participants played both FP and TP, presented in two separate, counterbalanced, blocks. Results: Spending increases with the number of MUs taken by A (i.e. the degree of unfairness) in both FP and TP ($\chi2$= 1015.71, p<.001); spending is higher in FP ($\chi2$= 19.19, p<.001). Interestingly, in TP, participants are more likely to compensate than to punish ($\chi2$=12.54, p<.001). Imaging results (whole-brain, cluster-level FWE p<.05, unless otherwise stated) show that DLPFC and right anterior insula (small volume corrected (SVC)- , FWE p<0.05) increase in activation parametrically with the unfairness level in both FP and TP. Caudate is more active in FP than in TP decisions, and this activation in FP is higher (SVC, FWE p<0.05) for trials in which participants punish. We then divided participants into Compensators (N=19) and Punishers (N=14) based on TP preference (N=5 never spent). In TP decisions, activation in right middle temporal gyrus and TPJ (i.e. Theory of Mind areas) is higher in Compensators. When their preferred option is available ("increase B" or "decrease A"), both groups show an increase (SVC, FWE p<0.05) in ventral MPFC and striatum (i.e., reward areas). Conclusions: At a societal level, it is evident that people often act against their self-interest in order to respond to injustice, even when they are not personally involved. Our brain data suggest that taking another's perspective may be related to compensation, and that reacting to unfairness in our preferred way is rewarding. Notably, people spend more when they themselves are victims. This finding, together with the caudate activation found for FP punishment, supports the hypothesis that punishment is more rewarding when we are personally involved.

3-L-49   Distinguishing different psychiatric populations based on a social hierarchy paradigm

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Introduction Anti-Social Personality Disorder (ASPD) and Borderline Personality Disorder (BPD) are psychopathologies characterized by profoundly aberrant interpersonal behaviour. They strongly affect the lives of both individual patients and those around them. BPDs and ASPDs share many behavioural characteristics, such as impulsivity and difficulty in sustaining long-lasting social relationships, and although they are considered different disorders, the distinction between them is sometimes blurry1.

Amongst clinicians and scientists there is a growing interest in novel approaches to psychiatric disease classification that allow for better understanding and distinction of psychiatric diseases, based on potentially quantifiable traits. Here, we use a Social Hierarchy decision-making paradigm and apply computational models to the obtained behaviour to understand better the differences between BPDs, ASPDs and controls, and how these diseases impact social decision making. Methods As part of a large-scale computational psychiatry program, 159 BPDs, 12 ASPDs and 103 healthy controls (total n=274) participated in a multi-round social exchange paradigm, the Social Hierarchy (SH) game. In each round of the SH game one of the players ('alpha') receives a given sum of money and decides how to split it with the other player ('beta'). Then, the beta player has the chance to 'challenge' the alpha's position. If there is a challenge, both alpha and beta decide by how much to challenge (beta) or defend (alpha). Whoever spends the most assumes the alpha position in the next round. The SH game is played for 30 rounds, always with the same opponent (here a computer algorithm mimicking a real person). Results We found that ASPD participants spent significantly more on average on contests and left their opponent with lower final earnings compared to both controls and BPDs. For the BPDs, model agnostic approaches did not show them to differ significantly from healthy controls, but a logistic regression model relating challenge decision to amount transferred showed BPDs had a higher baseline tendency to challenge and were more sensitive to the amount of money transferred by the opponent. We also started doing cross-validated model-based analyses of participants? behaviour and are obtaining interesting results. Conclusions Our results suggest that ASPDs value social dominance more than healthy controls and BPDs, whilst the latter are particularly sensitive to social signals. These results suggest that ASPD and BPD may be two actual separate diagnoses, and offer promising avenues by which different psychiatric disease states could be distinguished at the mechanistic level.

3-L-50   The Effect of Intranasal Oxytocin on Indirect Reciprocity

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Objective: Indirect reciprocity (IR) refers to the phenomenon that people help strangers although they might never encounter this person again. Third-party (TP) reputation-based reciprocity and pay-it-forward (PIF) reciprocity are two forms of IR. The former means that people are willing to altruistically punish unfair behavior of strangers and the later means that people help a stranger after being helped by someone else. Although intranasal oxytocin (OXT) has been found to promote pro-social behavior, its effect on these two forms of IR has not been investigated so far. Methods: We recruited 132 healthy male participants (pps) who performed two independent tasks (TP and PIF). A placebo-controlled, double-blind, between-subject design was adopted. The TP task consisted of 3 rounds. In each round, pps received a 10-Euro endowment and were presented one of three possible money splits proposed by a Player A to Player B (i.e. 9/1, 6/4 or 5/5). Their task was to decide whether to decrease Player A's payoff (i.e. punish), to increase Player B's payoff (i.e. help; and further indicated the exact amount in either case), or to keep the money to themselves. Furthermore, pps rated the unfairness level of the money split on a 9-point scale. The PIF task consisted of 2 rounds. In each round, pps received either an equal or an unequal money split from a Player X (i.e. 9/1 or 5/5). Then pps were endowed with 10 Euro and decided whether to allocate certain amount of this to a Player Y (and further indicated the exact amount if so) or to keep the money to themselves. Pps also rated the unfairness level of the split received from Player X on a 9-point scale. Notably, all players in both tasks were anonymous to pps. The order of tasks was counterbalanced across pps; the display order of splits as well as the choice options

was randomized within pps. Finally, one round of either task was randomly selected to be payoff-relevant. Regression was used to analyze the behavioral data. Results: In the TP task, pps are more likely to punish and help with increasing inequality of the split. Furthermore, OXT accelerated punishment behavior on average, and reduced unfairness rating with increasing inequality of the split. In the PIF task, pps were more likely to share their money with someone else when they received an equal split previously. Moreover, we found an interaction between OXT and decision type (i.e. keep or allocate) on decision time, especially for those pps who were not always selfish. In particular, those pps reduced the time to allocate but prolonged the keep choice in OXT. Conclusion: Our results extend the knowledge of pro-social effect of OXT to IR.

3-L-51   More demanding with the beauties in asset division: evidences from an ERP study
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Is beauty rewarding? Evidences from brain imaging and EEG data gave out some positive answers. Our two previous studies used modified ultimatum game to investigate the neural basis of beauty premium effect in social interactions and showed that attractive female do enjoy some advantages in asset division no matter they played as allocators (Ma, Hu, et al, 2015) or powerless recipients (Ma and Hu, 2015). Could beauty be a "curse" in some situation? A theory of beauty penalty was brought out in a trust game (Wilson and Eckel, 2006) suggesting that attractive people were also expected to behave with a higher morality and punishment would arise higher when they failed the expectation. In this study, we incorporated intention-based consideration to examine this stereotype. Twenty male subjects were recruited to participant in a two-person ultimatum game and measure their neural responses towards perceived intention of female allocators with varied facial attractiveness by an event-related potential (ERP) method. The behavioral data supported the beauty premium effect that offers proposed with a bad intention by attractive females were rejected less than unattractive females. However, ERP data elucidated a different preference pattern that bad-intention offers proposed by the beauty elicited a more negative feedback-related negativity (FRN) compared to offers given by unattractive females, as FRN normally indexes a deviation between potential payoffs and actual outcomes that the larger prediction error is, the more negatively FRN deflects. Additionally, good/bad intention comparison in the attractive-face condition induced a significantly larger FRN discrepancy than that in the unattractive-face condition. No significant interaction effect between intention and facial attractiveness was observed for P300 component, with a more positive waveform generated in good-intention conditions. In summary, this study provided neural evidences of how male subjects responded to attractive and unattractive female allocators' behavioral intention of splitting a certain asset. FRN data showed that male subject tended to expect more from attractive allocators compared to unattractive allocators, when this expectation was dashed, generated a larger FRN. Meanwhile, the discrepancy between behavioral and neural data could possibly be explained by P300's immune to beauty effect in late process.

3-L-52   Taboo for you?: Neurocomputational modeling reveals novel insights into sacred values and cost-benefit tradeoffs
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Objective: Many economic models assume that choices are made using a weighted sum of costs and benefits. Thus, costs should be accepted if they are offset by sufficient benefits. Yet a class of moral

choices involving "sacred values" appears to violate this assumption: decision makers act as if some moral values cannot be weighed against more secular benefits (e.g., "You can't put a price on human life"). When people reject such "taboo tradeoffs", are they failing to consider offsetting benefits, or do they evaluate these benefits and simply find them insufficient to override compelling moral interests? Previous research has had difficulty answering this question because it typically uses hypothetical scenarios. Invariant behavior (i.e., 100% rejection) also makes it hard to determine whether value is placed on benefits. Methods: To address these issues, we applied neurocomputational insights to a novel moral choice task with real consequences. Observant Muslims chose whether to eat different quantities of appetitive foods, morally unclean non-Halal foods, and aversive-but-Halal foods for different amounts of money. Choice movements were tracked continuously using a computer mouse. Pps then made subjective ratings of liking, disgust, and moral revulsion for each of the foods seen in the choice task. Computational simulations using drift diffusion models predict that if Pps consider monetary benefits, larger payoffs to eat aversive food should make the choice more difficult (i.e. longer RTs), even if the proposal is consistently rejected. In contrast, if the taboo against non-halal foods prevents consideration of monetary benefits, no RT differences should emerge even with substantial differences in monetary payoff. We analyzed choices, RTs, and continuous movement dynamics to test these predictions. Results: Choices for aversive-but-Halal foods closely followed computational predictions: larger monetary payoffs produced increased acceptance rates and longer RTs (suggesting that Pps integrated both costs and benefits to make a choice). Intriguingly, although Muslims consistently rejected non-Halal foods, RTs nevertheless went up for larger amounts of money, indicating a subtle sensitivity to benefits. Dynamic movements revealed that this effect arose from a late-emerging consideration of both monetary benefits and moral costs. Conclusions: Our results suggest that people consider benefits from taboo tradeoffs even when consistently rejecting them. Dynamics of choice also hint that the "gut" instinct to say no may be followed by more reasoned consideration of costs and benefits. Neuroimaging to elucidate underlying mechanisms is currently in progress.

3-L-53   What is beautiful is trustworthy - neuroanatomic and -functional correlates of the Halo effect

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Physically attractive persons are perceived to possess more socially desirable personality traits, such as trustworthiness, than physically unattractive persons; an effect also referred to as Halo effect. Although this phenomenon is widely observed in human society, its neural basis is uninvestigated. Also, it is unclear whether this is a mere momentary bias during the judgement situation or a more stable, hardwired cognitive ability. Here, we investigated the neuroanatomical and -functional correlates of the Halo effect in 33 (19 females) healthy subjects using magnetic resonance imaging, while subjects were viewing faces. The individual degree of the Halo effect was assessed 1) immediately after the scanning and 2) 5 years later, with which we demonstrate the extreme persistence and stability of the Halo effect (r=0.62; p<0.05). Supporting this behavioral persistence, a VBM analysis revealed that the grey matter density of amygdala significantly predicts the individual differences in Halo effect. Furthermore, we show that the amygdala changes its functional connectivity with the striatum when subjects are viewing attractive vs. non-attractive faces. This amygdala-striatal connectivity change is significantly modulated by individual differences in the Halo effect. The Halo effect is thought to be a major candidate mechanism leading to stereotype. Our results powerfully demonstrate the persistence of the Halo effect, how it is anchored in the brain structure and its impact on brain function during social cognition.

3-L-54   **Description versus Experience: Sources of Expectation in the Ultimatum Game**

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Introduction: Being treated fairly by others is an important social need. Experimentally, fairness can be studied using the Ultimatum Game in which the decision to reject a low, but non-zero, offer is seen as a way to punish the other player for an unacceptable division. The canonical explanation of such behavior is inequity aversion: people prefer equal outcomes over personal gains. However, there is abundant evidence that the decision to reject a low offer can be changed by both contextual factors and emotional state, which cannot be satisfactorily explained by the inequity aversion model. A recent alternative explanation proposes that the main driving force behind the decision to reject is that of deviation from expectations: the larger the difference between the actual offer and the expected offer, the more likely one is to reject the offer. In analogy to the description-experience gap in risky decision-making, we tested and extended this idea by providing participants with information on what kind of offers to expect in two forms, either via a summary graph or by showing offers one-by-one. Methods: Each participant played as the responder in the Ultimatum Game with eight groups of proposers. Before playing, participants were provided with information as to what kind of offers to expect by indicating what the current group of partners supposedly offered in a previous experiment. In the "experience" block, the "previous" offers were shown one by one; in the "description" block, the same information was provided in form of histograms. In each block, participants played with four different groups, where both the mean and the variance varied in a 2x2 design. Data were analyzed using a logistic mixed-model analysis. Results: As expected, we found that the decision to accept or reject a certain offer was dependent on the information provided. Importantly, we find that the mean and variance of expected offers affected the decision to accept. Specifically, when expecting low offers, participants were more likely to accept unfair offers; when expecting high variance, participants were more likely to accept. In addition, we found that providing participants with information by showing them one offer at a time lead participants to reject the same offers slightly more often. Conclusions: These results demonstrate the complex nature of social expectations, which might be better conceptualized as distributions instead of simple mean expected values, and how they influence considerations of fairness. Further, our findings demonstrate a small description-experience gap in the domain of social decision-making.

3-L-55   **Social preferences and socially responsible investing: A survey of US individual investors**

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We conduct a survey of social preferences among US investors to examine whether social preferences can explain three measures of engagement in socially responsible investment (SRI): interest in SRI; history of SRI investment; and the proportion currently invested in SRI. We find that investors with stronger social preferences are significantly more interested in SRI than are those with weaker social preferences. Further, investors with stronger social preferences are more likely to have invested in SRI. We do not, however, find any association between social preferences and the share of total portfolio invested in SRI. Our results lend support to the notion that the decision of individual investors to invest in SRI arises, at least in part, from social preferences.

3-L-56   **The role of the temporo-parietal junction and dorsolateral prefrontal cortex in third-party punishment of norm violations**

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Objective: Cooperation in human societies is greatly affected by social norms. Furthermore, people are often willing to punish norm violations at a substantial personal cost (Fehr,Fischbacher, 2004). People feel sympathy/empathy with the victim of norm violations (Gromet,Darley, 2009) and experience strong negative affect that leads them to punish the offender (Fehr,Gächter, 2002). It has been found that the right dorsolateral prefrontal cortex (DLPFC) is causally involved in decisions to enforce social norms. For example, inhibition of the right DLPFC by repetitive transcranial magnetic stimulation (rTMS) increased the frequency of third-party punishment during the Dictator Game (Brüne et al, 2012). Importantly, social sanctions may also be driven by in-group favoritism and out-group hostility ("parochialism"). Baumgartner and colleagues (2014) demonstrated that rTMS of the temporo-parietal junction (rTPJ) reduced parochial punishment in a third-party punishment paradigm with real social groups. Here we test the hypothesis that a decision to punish in a third-party punishment paradigm depends on the activity of the entire rDLPFC-rTPJ network. Methods: To check our hypothesis, we used transcranial direct-current stimulation (tDCS) to disrupt the rDLPFC-rTPJ network in healthy subjects while they performed the Dictator Game. During separate sessions (within-subject design), we applied tDCS simultaneously to rDLPFC and rTPJ using three stimulation protocols: Condition N1, cathodal tDCS of the right DLPFC and anodal tDCS of the right TPJ; Condition N2, anodal tDCS of the right DLPFC and cathodal tDCS of the right TPJ; and Condition N3, a sham stimulation of the right DLPFC and TPJ. We counterbalanced tDCS stimulation conditions across subjects. Additionally, we estimated perspective-taking of subjects by Russian Version of Interpersonal Reactivity Index questionnaire (Davis, 1980). Results: Our pilot study (n=16) suggests that the frequency of third-party punishment near-significantly increased in Conditions N1 and N2 as compared to the control, Condition N3. Importantly, when the individual level of perspective-taking was taken as a covariate, the effect of tDCS reached the level of significance ($F = 3,279$, $p = .03$). Conclusions: To the best of our knowledge, this is the first study demonstrating the effect of simultaneous tDCS of the rDLPFC and rTPJ on the frequency of third-party punishment. We also show that the observed effect of tDCS during the Dictator Game is modulated by individual differences in perspective-taking Acknowledgements: The study is funded by the Russian Academic Excellence Project '5-100'.

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