Association between a dopamine β-hydroxylase promoter Region SNP (-1021C/T) and autism-related traits

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Abstract:

It has been widely recognized that deficits in social decision-making and cognition are key features of autism. Such deficits are thought to reflect in part dysfunction of central catecholamine neurotransmission. We have studied in normal subjects autism-related cognitive traits and tested for association with a putative functional promoter region polymorphism, rs1611115 (−1021C/T) in the DBH gene that encodes the final enzyme in the conversion of tyrosine to norepinephrine, linked in some studies with decision-making, impulsive behaviors and addiction among others. We found that the subjects with CC genotype display better performance in the reading the mind in the eyes test (RMET), a measure in which subjects with autism show poor performance. Interestingly, compared with subjects with CC genotype, the T carriers reported a relatively higher score in the Autism Quotient as well as the personality trait of Harm Avoidance. Taken together, these findings indicate that this DBH gene polymorphism contributes to shaping social phenotypes relevant to autism, altogether suggesting a key role of DBH and noradrenergic neurotransmission in social decision-making.

Neural Mechanisms of Risky Choice Framing Effects Vary with Numeracy and Metacognition

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Objective: Framing effects are context-dependent risk preferences driven by categorical comparisons of numerical information. Although numeracy affects risky decision making in many contexts, its contributions to the neural mechanisms of risky choice framing are unknown. We tested the hypothesis that, when deciding between options of equal expected value, more numerate individuals would be better able to extract the bottom-line meaning of numerical information, producing categorical comparisons that, ironically, lead to increased framing effects.

Methods: Thirty-two adults answered 60 risky choice framing problems about lives and money in an MRI scanner. In each problem (e.g., 600 lives are at stake), the sure option (e.g., save 200 for sure) was held constant, and the risky option (e.g., 1/3 chance save 600, 2/3 chance save no one) was truncated to emphasize or de-emphasize the categorical comparison with the sure option. Subjects completed the Cognitive Reflection Test (Frederick, 2005) and Subjective and Objective Numeracy Scales (Reyna et al., 2009). BOLD response and functional connectivity during decisions were regressed against subjects' numeracy scores, identifying brain regions whose activation in a given contrast varied with numerical and metacognitive ability.

Results: Across the entire sample, as predicted, framing effects increased in the condition that emphasized categorical comparisons but decreased in the condition that emphasized numerical precision. However, high numerates framed more than did low numerates in the condition that discouraged framing. During standard framing decisions, higher scores on numeracy and metacognition scales were associated with more activation in the frontopolar cortex (BA 10), DLPFC, and ACC.

Conclusions: Although many theories assume that more numerate individuals would be less susceptible to framing effects, we found the opposite: More numerate subjects framed more in the condition that discouraged framing bias. Our results suggest that high numerates mentally generated the missing zero complement in the risky option, thereby transforming this version of the problem into the one that encouraged framing effects. In more numerate subjects, framing effects were supported by regions associated with metacognition, monitoring, and conflict detection. These results suggest that high numeracy sharpens perception of context-dependent qualitative differences, and also sharpens detection of conflict between qualitative and precise numerical representations.

Behavioral and neural effects of highlighting monetary gain in the Ultimatum Game

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Objective:
There is a growing body of evidence indicating that ventromedial and right dorsolateral prefrontal cortex (vmPFC and dlPFC) play a central role in determining the impact of fairness deviations on behavior in the ultimatum game (UG). Here, we explicitly modulated subjects' focus towards monetary or fairness aspects of the decision while measuring neural activity with fMRI.

Methods:
25 adults (11 female) played the UG, deciding whether to accept or reject offers while undergoing fMRI. Trials were split into three block types (fairness focus, money focus, and 'natural choice') offers were balanced across blocks, but all unfair. Subjects were paid according to their choices for one randomly selected trial in addition to a show-up fee.

Results:
A behavioral mixed effects logistic regression analysis of ultimatum acceptance revealed that the fairness and monetary conditions led to more rejections or acceptances respectively (both significantly different to 'natural choice'). The offer and the percentage offered were significant predictors of accepting a distribution. For the congruent interactions (percentage offered in the fair condition and offer in the money condition), significantly positive effects were observed, as opposed to negative effects for the incongruent interactions. In addition, a dynamical model of decision-making revealed condition dependant differences in the influence of money and fairness on the rate of evidence accumulation for choice (i.e. the offer), as well as different choice bias terms between conditions At the neural level, we found corresponding differences between conditions in the strength of the correlation between monetary offer values and BOLD activity in vmPFC / anterior cingulate.

Conclusions:
These results suggest that relatively simple attention or cognitive focus manipulations can modulate value computations and the chosen response to monetary distribution proposals. In further analyses linking the computational model parameters to BOLD activity, should allow us to disentangle neural correlates of distinct components of the decision-making process such as the evidence accumulation rate for choice and inherent biases for fairness and monetary components of value.

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Short-term plasticity in auditory cortical circuit evoked by monetary incentive delay task

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Objective:
Many standard neuroeconomics models of decision-making assume that the primary sensory input to the neural networks involved in this process is stationary. We investigated the effects of the repeated monetary incentive delay task (MID-task; Knutson et al., 2005) on the short-term plasticity in the primary auditory cortex.

Methods:
Thirteen right-handed participants (8 males; age range 19-25) performed two 20-minutes sessions of the MID-task (auditory version) in two consecutive days (Day1 and 2). During each trial, subjects were exposed to one of four acoustic 'gain cues'. Next, subjects attempted to respond with a button press to the presentation of a visual target of varying duration. A feedback followed the disappearance of the target, which notified subjects how much money they had gained on that trial as well as their cumulative total. Gain cues signaled the possibility of winning 0.2 or 0.6 USD and its expected probability (such that subjects would succeed on 15% or 75% of trials). Thus, acoustic cues varied in relationship to the expected value (EV). Meanwhile, training-induced cortical plasticity was evaluated using an *odd-ball* paradigm, comparing the event-related potentials (ERP) in response to acoustic cues pattern before and after training. In our study we used changes in ERP (MMN and P3a) components characteristics as an index of central auditory system plasticity (Näätänen, 2008).

Results:
Preliminary results indicate that the repeated MID-task induced a significant enlargement of the P3a (but not MMN) component evoked by acoustic gain cues with the largest EV as compared to gain cues with the lowest EV at fronto-parietal electrodes. Three-way ANOVA with factors *Session* (Day1, Day2), *Electrode* (Fz, Pz, Fc1, Fc2) and *EV* (low, high) showed a significant interaction *Session* x *Electrode* x *EV*, $F(3,30)=4,7$; $p=0.01$.

Conclusions:
The P3a has been associated with brain activity underling involuntary attention switching (Yeung & Sanfey, 2004). Our results suggest that the repeated MID-task switches the involuntary attention to cues signaling the largest EV. Overall, the MID-task not only probes the activity of valuation neural circuitry, but also evokes a short-term plasticity of the frontal cortex associated with the involuntary attention toward the cues with the highest values.

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Modulation of Judgments by Incidental Rewards: Evidence from Facial Affective Recording

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Objective

Why are all things better on a sunny day? Previous behavioral decision making research has shown that people rely on "feelings as information" to make judgments, even if these feelings are unrelated to judgments (Schwarz & Clore, 1996). However, a recent fMRI study showed that it is unclear how the brain integrates incidental feelings into subsequent judgments (Plassmann et al. 2014) and research about better understanding the temporal dynamics of this integration of unrelated feelings as information in judgments is needed. This research explores how other physiological measures with a higher temporal resolution, that is facial affective reactions, correlate with feelings-as-information effects.

Methods

Participants faces (N=17) were recorded using a video camera while engaging in a task that first involved the receipt of a monetary reward (€0 or €15), and subsequently the exposure to either an affectively positive or neutral image for 7.5s. Subjects then rated their enjoyment of seeing the image (9-point scale, 1="not at all" to 9="very much"). The video footage was analyzed using an automated facial affective encoding software (FaceReader^{TM}, Noldus Information Technology).

Results

Behavioral Ratings: Repeated measures ANOVA revealed a main effect of reward type ($F_{(1,16)}$=12.34, p=0.003), a main effect of image type ($F_{(1,16)}$=44.6, p<0.001), but no interaction effect ($F_{(1,16)}$=0.72, p=0.41). These results replicated previous findings that incidental rewards significantly altered subjects' enjoyment of viewing the images such that subjects liked the positive and neutral images more after receiving the incidental reward relative to no reward.

Facial Affective Valence (FAV): We ran a set of analyses on averaged FAV and temporal dynamics of FAV per 500ms intervals to examine whether the incidental reward altered FAV while viewing the images. We found significantly higher FAV when subjects received a reward vs. no reward ($F_{(1,16)}$=4.82, p=0.043). We also found a marginally significant main effect of image type ($F_{(1,16)}$=3.97, p=0.064), but no interaction effect ($F_{(1,16)}$=0.1, p=0.75). The mean FAV was significantly higher for viewing positive and neutral images after receiving the incidental reward relative to no reward. Analysis of temporal dynamics of FAV shed light on when incidental rewards were encoded into judgments (see Fig 1).

Conclusions

Our results show that the incidental rewards have an effect on reported liking and also implicit facial affective valence.

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Reward? What Reward? Probabilistic Reversal Learning in Depression

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Objective: Prior research shows that individuals diagnosed with major depression exhibit impaired performance in probabilistic reversal learning tasks. Poorer performance on these tasks, though, could be due to many different factors: an inability to understand the task, perseveration or bias for a particular stimulus or side, interference between action and stimulus learning, a deficit specific to reversals, hyposensitivity to reward, hypersensitivity to punishment, etc. The purpose of the present study was to examine what accounts for poorer probabilistic reversal learning in depressed individuals.

Methods: Sixty-four clinically depressed and sixty-four healthy controls participated in both a reward-based and punishment-based probabilistic reversal learning task. The depressed group did not differ from the healthy control group with respect to age, gender, ethnicity, education and IQ. For the reward task participants choose between two fractal stimuli. Positive feedback is provided if a fractal is reinforced with a reward (picture of a coin); otherwise, neutral feedback is provided (a red dot; indicating no coin). The fractals are probabilistically rewarded; with the richer fractal rewarded 70% of the time and the poorer fractal rewarded 30% of the time. Participants are informed that on any given trial, one fractal has a higher likelihood of delivering a reward and this association reverses periodically throughout the task. All participants complete 4 trials as practice before proceeding to do a full run of 90 trials. The punishment task is similar to the reward learning task except, the goal for the participant is to try to avoid choosing the fractal leading to punishment feedback (red cross overlaying a coin). Participants were compensated for their participation and paid according to their performance.

Results: Depressed individuals chose the higher probability target less often in both learning tasks and performed significantly worse on the punishment task ($p = 0.001$, $d = 0.58$). Depressed participants were significantly less likely to stay after winning in the reward task ($p = 0.002$, $d = 3.84$) and significantly less likely to stay after "winning" (i.e., not losing) in the punishment task ($p = 0.002$, $d = 4.55$). Poorer performance was not explained by a reversal deficit, as the difference between depressed and controls was present from the first block. We explored a range of reinforcement learning models for their ability to explain choice behavior in the two groups. Poorer performance in the depressed group was captured best by a lower learning rate for this group in the model.

Conclusion: The results suggest that depression is characterized by deficits in probabilistic reversal learning that are best captured by a reduced impact of rewards on learning rather than a misunderstanding of the task, an inability to make reversals, perseveration or bias, etc. This deficit was best captured by computational reinforcement learning models with a lower learning rate in depressed individuals, a behavioral finding that is mirrored by the neural finding in several studies that depressed individuals exhibit reduced ventral striatal prediction error signals.

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Choosing to make an effort and preparing to overcome it: the role of the Anterior Cingulate Cortex.

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Objective: In a natural environment, benefits mostly come at a cost. Pursuing a reward usually requires some effort. Anticipating both potential rewards effort requirements is therefore an essential skill in driving adaptive behavior. However, the underlying neural mechanisms are still debated. A net-value account has been proposed, according to which the value of the reward is discounted by the effort implied in obtaining it. This computation would be implemented by the Anterior Cingulate Cortex (ACC), as suggested by neurophysiological evidence in animals and neuroimaging studies in humans (Rushworth and Behrens, 2008, Croxson et al. 2009, Kennerley et al. 2009). However, this theory has been recently challenged by incompatible results, showing that ACC supports a motivational encoding of effort instead (Vassena et al. 2014). According to this motivational account, ACC activity is essential in prompting and sustaining effortful behavior towards the achievement of a goal (Holroyd and Yeung, 2012). The purpose of the current study was to directly test the divergent predictions arising from these accounts, incorporating an additional crucial factor: decision-making. Previous studies did not differentiate between effort-related decision-making and anticipation of effort when no choice was required. Given the pivotal contribution of ACC to decision-making processes, controlling for this factor is crucial to disentangle effort encoding in the ACC.

Methods: To this end, a cognitive effort fMRI paradigm was implemented, consisting of two phases: a decision-making phase and a performance phase. This allowed to systematically investigate effort encoding both during decision and during anticipation in the same subjects. Moreover effort was manipulated parametrically, to test for linear encoding.

Results: The results are in line with the prediction of the motivational account, showing increased ACC activity as a function of required effort, across both decision-making and phase. No evidence for the net-value account was found. Furthermore, a targeted ROI analysis revealed a modulation of phase, showing an inverted U shaped relationship between effort encoding during decision and ACC activity in the low reward condition.

Conclusions: These results show a pivotal role of ACC in encoding effort in a motivational fashion, prompting engagement in effortful behavior only when this is considered worth. This data provides empirical support for recent accounts of ACC function.

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Episodic context of cued past choices can bias subsequent decisions for reward

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Objective: We investigated whether choices can be biased by manipulating the context of cue-evoked episodic memories. Recently, a family of action selection algorithms called "decisions-by-sampling" have gained influence in the study of decisions for reward. They differ from value learning models (e.g. Temporal-Difference learning - TDRL), as they evaluate options at choice time by remembering past outcomes. This approach reproduces idiosyncratic features of choice unexplained by TDRL (Erev, Ert, Yechiam 2008). We aimed to alter this sampling process by taking advantage of features of the episodic memory system.

Previously we showed that reminding subjects of particular past choice trial episodes - using incidental presentations of image cues uniquely associated with those trials - biases subsequent decisions (Bornstein, Khaw, Daw *submitted*). Current episodic memory models predict that when a past episode is brought to mind, contextual features are also reinstated. We hypothesized that retrieval of context information will boost sampling of other trials that share those contextual features, which should *also* bias subsequent decisions.

Methods: 20 participants each made 180 choices in a three-armed bandit task taking place across six virtual "rooms". Each room was distinguished by a different scene image in the background. In a seventh "room" with no background image, participants made 120 additional choices, interspersed with 60 incidental reminders of past trials. To dissociate the contribution of the reminded trial from that of other trials in the same room context, we reminded participants of trials where the rewarded (and chosen) option was distinct from the option that would be most often rewarded in that room. Critically, trials that distinguish context reward from the reminded trial reward happen *after* the remembered trial.

Results: The key measurement is the effect of the average reward received for the chosen option in the reminded context room. We entered this "context reward" in a multiple regression alongside the reward received on the reminded trial and the recent history of choice outcomes. Context reward was a significant predictor of choices after a reminder trial, over and above the other variables ($p < 0.05$ across participants; effect size approximately equivalent to a reward received between one and two trials ago).

Conclusions: These data provide evidence that choice models may be improved by incorporating episodic memory. Episodic information is omnipresent in naturalistic choice situations, and may be incorporated into the design of treatments and interventions.

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Activation profiles in number processing brain regions predict discount rates in intertemporal choice

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Objective: The trade-off between smaller, sooner and larger, later rewards – intertemporal choice – is ubiquitous in every-day life, and decision-makers vary widely in their intertemporal preferences. Using functional magnetic resonance imaging (fMRI), we tested whether individual differences in intertemporal preferences were related to differences in activation profiles in brain regions involved in early number processing.

Methods: Forty-seven healthy adult participants made a series of choices between fixed immediate and variable delayed monetary rewards while whole-brain fMRI was conducted. Critically, monetary amounts and delays of the delayed rewards were presented sequentially to dissociate the two attributes, and the order of amount and delay was counterbalanced. BOLD responses in inferior and superior parietal lobes (IPL/SPL; BA7/40), previously implicated in number processing, as well as in ventral medial prefrontal cortex (VMPFC) and ventral striatum (VS), previously linked to value processing, were analysed using separate parametric regressors for magnitude of delay and monetary amount. Finally, percent signal change was correlated with discount rates at a subject level.

Results: Numerical magnitude of both amount and delay were encoded in IPL/SPL while VMPFC and VS encoded value (Fig. 1). Moreover, individual discount rates were correlated with the mean BOLD response (r = -0.36) in IPL (R^2 = 13.2%; Fig. 2A) as well as the curvature of the BOLD response in IPL (r = -0.32, R^2 = 10.3%; Fig. 2C).

Conclusions: Our results demonstrate that heterogeneity in discount rates was substantially related to activation differences in brain regions involved in number processing. This suggests that the initial processing of numeric entities might elicit a stronger bias on intertemporal choice than previously acknowledged, also providing new avenues for the investigation of pathological choice behaviour in clinical populations.

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The value representation of collections of goods for losses is not gain-loss context dependent.

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Objective: Traditionally, economists use the "indifference curve" to describe value representations (utilities) of combinations of goods which an individual finds equally desirable. By presenting people with choices between many "bundles" (a collection of goods), for instance bundle A (4 boxes of milk and 4 pieces of chocolate) or bundle B (5 boxes of milk and 3 pieces of chocolate), all the bundles which offer that chooser the same utility can be graphically identified. One of the assumptions many models of indifference curves makes is that each of the goods in a bundle presents a decision-maker with a diminishing marginal utility as the number of that bundle element increases. It predicts that people are more willing to give up one box of milk for one piece of chocolate when they already have a lot of milk, but less willing to give up one box of milk when they have fewer boxes of milk. However, many Prospect Theoretic based models, which describes subjects with increasing marginal utility for losses, predict that in the domain of losses, the opposite of this usual pattern should obtain. Perhaps surprisingly, this fundamental prediction of indifference curves has never been empirically tested at the behavioral level. Here, we propose two hypotheses for indifference curves under losses. First, the classical theory predicts a concave curvature, which is the combination of diminishing marginal utility in the domain of losses. Second, Prospect Theory might be thought to predict convex curvature –suggesting an increasing marginal utility for goods in losses.

Methods: There were four tasks ("bundle-gain task", "bundle-loss task", "gamble-gain task", and "gamble-loss task") in this study. These tasks were designed to measure indifference curves in an incentive compatible procedure in the domain of gains and losses while also characterizing individual choosers' utility function of each of the goods (within bundles, as both gains and losses). The visual stimuli were identical in all tasks and participants were instructed similarly in all tasks: make a series of choices between two options.

Results: Our preliminary data support our first hypothesis. We found that indifference curves are concave, which is the combination of diminishing marginal utility, not only for gains but also for losses. This finding is not compatible with gain-loss context dependent utility theories. However, based on the preliminary data, participant's utility of each goods is gain-loss context dependent. Most subjects showed clear evidence of risk-seeking for losses, the increasing marginal utility consisted with standard Prospect Theory, and risk-aversion for gains.

Conclusions: As we turn to the neural implementation of choice, this seems a critical distinction as it suggests that the increasing marginal utility under losses, which is a core feature of Prospect Theory, cannot be observed in the domain of consuming collections of goods. The properties of value representations under different situations might be different.

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Decision-making under risk and ambiguity in a broad(er) population.

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Abstract:

Individual attitudes towards known risks have been studied extensively not only in the lab with student populations, but also outside the lab with participant pools representative of the general population. These studies have provided us with a general understanding of the sources of heterogeneity in attitudes towards known risks. However, our everyday decision-making more often involves tradeoffs between options that involve risks that are *unknown*, rather than known to us. The sources of individual heterogeneity towards *unknown* risks (ambiguous conditions) have not yet been well understood. In a large-scale experimental study we therefore looked for demographic and socioeconomic sources of individual variation towards unknown (ambiguous) risks as well as known risks, choice rationality and consistency.

To this end, we present data from approximately two thousand volunteers who participated in an incentive-compatible experiment in the Marian Koshland Museum of the National Academy of Sciences in Washington, DC. The experiment was presented at museum kiosks and has been available to museum attendees for approximately two years. The incentive compatible instrument administered at the kiosks was designed to elicit individual attitudes towards known and unknown risks as well as choice rationality and consistency. Each participant filled out a demographic and socio-economic questionnaire.

We find large heterogeneity in attitudes towards unknown and known risks, and choice rationality and consistency. We find that a part of this heterogeneity can be explained by demographic and socio-economic differences between the individuals: age, gender, birth order, wealth, marital status, and employment status.

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Prospective Physical Effort and Decision Making Under Risk

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Objectives We often face choices that require consideration of physical effort costs with the possibility of gains or losses relative to the status quo. Previous studies of effort have tested the influence of anticipation or forced production upon discounting of the neural and behavioral correlates of decision values. To further resolve the influence of effort costs in choice, we assessed prospective effort, effort valuation separated from production.

Methods We modified the task from Tom et al. (2007) to evaluate risk attitudes under different potential physical effort levels. Subjects were first endowed with $10 (n=40 19 F, mean age 22.5) and completed a training phase that required them to produce grip force effort at 5 calibrated difficulty levels (30,40,50,60 and 70% of maximum voluntary contraction force). In a modified mixed gambles task, subjects accepted or rejected gambles (gains $2-12, losses $1-6) associated with the requirement of performing one of the grip force levels 5 times successfully at the end of the experiment to earn the gain, avoid the loss. One trial was selected at random and resolved according to the subject's choice.

Results Behavioral results demonstrated an effect of prospective effort level upon overall risk preference ($F_{(4,195)}$=29.67, p<.01), whereby greater prospective effort reduced overall willingness to gamble. Greater effort level also increased subjects' loss aversion ($F_{(4,195)}$=7.88, p<.01), by increasing sensitivity to losses over equivalent gains. Neuroimaging analyses (whole-brain cluster-corrected, $p < .05$) identified parametric modulation of brain regions for each gamble component. Increased gains and losses showed greater activity in a network of frontal and parietal regions previously implicated in common currency valuation. Increased effort prospects increased activity in anterior insular cortex, posterior prefrontal, and motor cortices, regions implicated in affective arousal, cost-benefit integration and motor planning respectively.

Conclusions Behavioral analyses show that prospective physical effort discounts signatures of value under risk. Neuroimaging analyses suggest that evaluation of prospective effort influences computation of decision values by recruiting brain regions related to selection and production of actions. These results support a novel role for these regions in decisions under risk.

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Measuring Perceived Emotional Value: New Insights from the Use of Physiological Measures?

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Objective: Perceived value related to products and product design comprises both cognitive and emotional facets. In particular, interdisciplinary research on product design stresses the fact that the design provides added emotional value to the consumer. Moreover, design is thought to be about far more than just visual aspects, in fact targeting the consumer at a subconscious level. Hence, explicit methods such as survey-based approaches might fall short of measuring these effects. The core aim of this paper is to conceptually discuss the ability of physiological measures to capture the emotional value associated with products and product design.

Methods: This paper is a conceptual piece. It aims at providing a contribution to the theoretical knowledge on the perceived emotional value of products and product design. First, it builds upon the extant literature on customer-perceived value, conceptualized as an integration of both cognitively as well as affectively toned value facets. Second, it relates to previous empirical findings on the role of product design within a consumption-related context. Third, all derived implications are based on the results of a sound discussion of the strengths and limitations of selected physiological and neuroscientific methods. The process applied follows one of conceptualization aimed at making a theoretical contribution. The paper further aims to contribute to the knowledge of how various physiological methods are able to capture the affectively toned facets of customer-perceived value relevant to products and their design.

Results: One major outcome of this paper is its comprehensive discussion of how different methods applied in consumer neuroscience may provide insights into the emotional aspects of value-related phenomena in a consumption context. As a method capable of measuring raw affective information processing, startle reflex modulation renders itself a suitable candidate for capturing the affectively toned facets of value related to products and product design. Self-report measures may capture the emotional value facets only to a limited extent, always remaining cognitive reflections of the raw affective information processing involved.

Conclusions: In today's fast-changing consumption society, emotional value facets related to products and design have become more crucial than ever before. Hence, a conceptual discussion of various methods capable of measuring these facets contributes not only to comprehensive scientific knowledge. It also serves as a basis for more informed managerial decisions in industrial design, marketing and advertising.

Applying Electroencephalography to the Study of Brand Attitude

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Objective: Traditional survey-based marketing research requires a verbal or written evaluation of a stimulus (in the present case a brand name). This process initiates the use of cognitive processes, which are reported to inevitably 'pollute' any affective responses. As companies begin to acknowledge that explicit measures, such as surveys, provide an unreliable and often inaccurate insight into their consumers' attitudes, the desire to find alternatives is increasing. The current study aims to discuss electroencephalography (EEG) as an implicit measure of consumer attitudes towards well-known brand names.

Methods: EEG, an objective measure of brain activity, was used to describe the spatio-temporal pattern, in other words the dynamics of neural processes that underlie attitudes towards brands. Twelve participants (eight female) were required to complete a survey regarding their attitudes towards 300 brands on a 21-point scale, prior to the laboratory experiment. From these ratings, a list of their 30 most positive, 30 most negative and 60 neutral brands (plus 80 fillers) was then compiled for each individual participant. During the lab experiment, the participants were again required to provide ratings of their attitudes towards each brand (explicit rating). In addition, brain potentials were recorded via EEG while the participants viewed each brand name.

Results: Interestingly, brands that were rated more positively (via self-report) were seen to elicit less negative brain potentials over the right frontal hemisphere than brands that were rated negatively. Hence, our results show EEG to be sensitive to consumer brand attitudes. This sensitivity is reflected in terms of the late positive potential (LPP). Existing literature supports the notion of a link between motivation and emotion. In terms of brands, if a consumer is motivated to make a purchase, it is assumed that they find the brand to be positive and vice versa. The literature supports this view and has shown that LPP effects in the frontal cortex are not only reflective of the valence of the stimuli being presented, but also of the motivational nature of the stimuli.

Conclusions: This research can be seen as contributing to a better understanding of consumer attitudes towards brands. Potential applications of this type of research are relevant to marketing research and practice alike. In addition, given the sensitivity of EEG in capturing consumer attitudes, it may be useful for determining the success of advertising strategies such as evaluative conditioning.

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Evaluative Conditioning: Different Methods, Different Insights?

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Objective: Effects of evaluative conditioning on established brands have been of interest for both researchers and practitioners of various business-related disciplines ever since. In this paper, the effect of evaluative conditioning is investigated using implicit and explicit measures. The aim is to determine how the different measures are differently sensitive to evaluative conditioning effects.

Methods: Twenty-one subjects (fourteen female) participated in the study. Evaluative conditioning effects on individually liked and disliked brands were measured via self-report, startle reflex modulation, heart rate, skin conductance and the implicit association test. The procedure of evaluative conditioning was achieved through repeated pairings of the brands with images that were pre-evaluated as positive or negative. Baseline measures were compared with measures taken after 1, 6 and 16 conditioning procedures.

Results: One major outcome of this study is that the measured impact of evaluative conditioning on established brand attitude depends on the measure used. Startle reflex modulation leads to different measures of evaluative conditioning than explicit ratings via self-report. Brand attitude is subject to evaluative conditioning, but in different ways for emotions compared to cognitions. Heart rate and skin conductance did not show any sensitivity to conditioning effects. However, startle reflex modulation and the implicit association test revealed significant conditioning effects, but more than one conditioning procedure was needed to cause a change. Most importantly, startle reflex modulation, the only implicit measure of raw affective processing, did show a significant evaluative conditioning effect only after six conditioning procedures and only in the case of disliked brands turning into better-liked brands. Since implicit measures are assumed to be more sensitive to deep underlying raw affective processing, it is concluded that startle reflex modulation can be seen as a valid method for detecting evaluative conditioning effects on an implicit level.

Conclusions: As a matter of fact, all measures that were used in the present study were differently sensitive to evaluative conditioning effects. This tells us, first, that an established attitude towards a brand indeed consists of various components, and second that evaluative conditioning has different impacts on these different components.

Neural Mechanisms of Stay/Leave Decisions

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Objective: People typically form relationships with each other, but may at times be faced with the decision to either stay with or leave a specific social partner. So far, relatively little is known about the underlying mechanisms of stay/leave decisions. The aim of this study was to explore the underlying psychological and neural mechanisms of stay/leave decisions, as well as compare these with decisions to stay with versus abandon a nonsocial resource.

Methods: Twenty-five subjects participated in the fMRI study, in which they played both nonsocial and social versions of the 4-armed bandit task. In the nonsocial version, on each trial participants selected between various slot machines and then viewed how much money they won. In the social version, participants chose between social partners and saw how much money the partner on that trial decided to share with them. Participants began the task with no knowledge of any payoff contingencies, and were free to decide to stay or leave with a partner on each trial.

Results: In both the social and nonsocial version of the task, decisions to stay or switch were strongly predicted by rewards obtained on each trial, as well as the reward difference between current and previous trial. Moreover, participant behavior in both social and non-social versions was predicted better than chance by standard Reinforcement Learning models. On a neural level, we saw no differential activity for decisions to leave social partners versus slot machines. Interestingly, however, we did find significant activation in bilateral superior temporal gyrus, left cuneus and anterior cingulate when participants decided to stay with a social partner as compared to when they decided to stay with a non-social partner.

Conclusions: Our results suggest that, at least in a context in which people can move freely between partners with no switch cost, similar mechanisms underlie stay/leave decisions for both social and nonsocial partners. However, results indicate that brain areas related to mentalizing are associated with decisions to stay with (but not leave) a rather than a social partner. We conclude that deciding to stay with a partner is related to reasoning about the intentions of our social partners.

Quantifying the Subjective Value of Metabolic Effort Cost

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Objective: While it is well-known that effort discounts reward, we surprisingly, do not yet have a good representation of the subjective value the brain assigns effort. Recent studies have reported a quadratic relationship, but they have used effort proxies, such as force, which may not represent physiological effort cost. Here, we seek to address this gap in our knowledge and measure physiological effort cost directly to quantify the subjective value of effort in units of effort (Joules). Specifically, we measured metabolic cost in a simple reaching task via expired gas analysis. This novel approach removes any confounds related to traditional proxies for effort such as force, temporally-dependent effort tasks such as button presses, or a distortion in monetary costs ($). We tested the hypothesis that there will be a distortion between subjective effort valuation and objective effort cost.

Methods: The first session involved performing 20cm reaches, during which metabolic rate was measured via expired gas analysis. Participants (n=13) reached against five different resistances. In the second session, they made choices between a sure bet of performing 5min of low effort reaches or risk performing higher effort reaches. The risky choice was presented as a % paired with one of the five resistances. The % represented the chance of having to reach for 5min at the presented resistance with the alternative outcome being sitting quietly for 5min. Using the metabolic data and the individual's choice data, the probability weighting, g, and subjective valuation of effort, α, were fit based on Cumulative Prospect Theory, using maximum likelihood estimation. We compared the performance of a model with a distortion parameter, α, and model where $\alpha = 1$(no-distortion).

Results: A model with a distortion parameter performed significantly better as determined by AIC comparison ($p < 0.01$). Specifically, 10 out of the 13 subjects exhibited a distortion between the subjective valuation and the objective cost of effort. The average γ across subjects was 0.57 +/- 0.11 (SE), consistent with previous findings. The average α across subjects was 1.14 +/- 0.09. Of the 13 subjects, the majority (9) overvalued the cost of effort ($\alpha>1$). Importantly, the measured exponent, α, is significantly less than the quadratic exponent, $\alpha = 2$, reported in studies using force as a proxy for physiological effort.

Conclusions: In a low-effort arm reaching task, individuals tend to overvalue metabolic effort cost. The observed distortion and variability among participants should be taken into consideration in models of decision making.

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IQ Predicts Individual Differences in Adaptive Learning

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Objective: Past work has shown that people are adaptive learners in a changing environment and are able to update their beliefs using relevant cues about the state of the world (Nassar et al., 2010). Despite common trends in behavior, there is great variability in subjects' learning strategies. We sought to identify cognitive and personality factors underlying these individual differences.

Methods: Forty-nine adult subjects (18-35 y.o.) performed a task allowing tracking of trial-by-trial learning. On each trial subjects positioned a bucket underneath a helicopter dropping bags of coins. Clouds obscured the helicopter, so subjects used previously observed bag drop locations to infer the helicopter's position. Bag drops were determined stochastically from a Gaussian distribution around the helicopter location. The helicopter location changed occasionally, giving rise to change points. Each bag contained coins that were either rewarded or unrewarded at the end of the experiment. Coin value was indicated by one of two colors and determined randomly on each trial, independently of helicopter position. We used a Bayesian ideal-observer model to simulate optimal behavior in this task. The model proposes two sources of influence on trial-by-trial learning rates: a parameter estimating the probability that the helicopter has changed location (change-point probability; CPP) and a parameter estimating the uncertainty in the exact location of the helicopter, often because of a recent change point (relative uncertainty; RU).

Subjects took the Big Five and Brief Sensation Seeking Scale, and had their IQ measured using the Wechsler Abbreviated Scale of Intelligence.

Results: Subjects, as a group, performed in accordance with the optimal model, adjusting bucket positions as a function of both CPP and RU. Subjects were also unduly influenced by coin value, making larger adjustments after bags with rewarded coins. IQ was positively correlated with several aspects of optimal task performance, including number of coins gathered and performance relative to the model. Specifically, IQ correlated positively with degree of bucket updating driven by both CPP and RU. However, IQ did not correlate with non-optimal bucket adjustments, such as those influenced by coin value. None of the personality measures (Big Five and Sensation Seeking) reliably predicted optimal behavior.

Conclusions: IQ, but not personality measures, predicts behavior on an adaptive learning task. These findings extend the range of decision-making behaviors affected by cognitive abilities and suggest that the latter should be controlled for in studying individual differences in decision-making.

Cognitive load and Time pressure effects moral judgments differently

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Objective: Trolley and similar dilemmas are widely used to study moral judgments involving utilitarian values. Based on dual process framework Cognitive load and time pressure is intended to decrease deliberation and therefore enhance the influence of affect on behavior. We here explore to which extent cognitive load / time pressure induces less utilitarian reasoning. In addition we explore to what extent phrasing scenarios as third-party or personal judgments influence moral inclination.

Methods: We apply four moral dilemmas previously used in the literature (Trolley, Footbridge, Deadly Gas, and Lifeboat). We run these moral dilemmas at three different location (Sweden n=710, Austria n=320 and USA n=583) applying time pressure and cognitive load, comparing with a neutral baseline treatment. We phrase the actual question in two different ways, is it morally the action morally appropriate vs how would you act in the describe situation

Results: Surprisingly we find significant effects in opposite direction when comparing cognitive load and time pressure. Time pressure increase utilitarian judgments while cognitive load has a tendency to decreases utilitarian judgments. This indicates that time pressure and cognitive load might involve different psychological mechanism. as expected females are significantly less utilitarian in their answers for all the dilemmas, effect size approximately 11% t-test p= <.0001 When adjusted for treatment females was still significantly less utilitarian in all dilemmas. Finally we see a significant negative effect on utilitarian judgment (t-test p= <.0001) when making third party judgments.

Conclusions: Cognitive load and time pressure is commonly used to invoke system 1 type of behavior, our results show that these might draw on different psychological mechanisms. Future research is needed to understand why and when time pressure and cognitive load influences moral behavior.

Third-party decision-making under risk following gains and losses

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Objective: Several decades of behavioral work have convincingly demonstrated individuals typically choose risky options more often when this choice occurs after experiencing a financial loss, while they generally prefer the safer option when the choice takes place after experiencing a gain. Living in a social environment entails that we not only make choices for ourselves, but also on behalf of others. It is unknown how financial gain/loss contexts affect risky choice on behalf of others. Here, we explored how third-party decision-making can influence risk preferences, and in particular examined whether third-party decisions altered risk preferences as a function of prior gain and loss framing contexts.

Methods: Participants (N=115) played a series of trials where they could either lose or win money depending on their performance on a time-estimation task. Immediately following the respective gain or loss, the participant then decided to either play or pass on a 50/50 mixed gamble that could either double or eliminate their gain (after a prior win) or redeem or double their deficit (after a prior loss). If they chose not to play this gamble, they retained the initial gain or loss. Participants played the task either for themselves ("*Self*") or for another, anonymous, participant ("*Third-Party*"). Additionally, we manipulated the degree of personal involvement when choosing in the Third-Party condition, by varying the extent of information being disclosed, about the decision-makers behavior.

Results: As expected, we found a significant shift in risk preferences following gains and losses when deciding for the Self, with participants gambling more after incurring a loss as compared to a gain (p<.001). This shift in risk preferences also occurred for Third-Party choices (for low and high personal involvement), however, it was a significantly *stronger* shift for Self-choices, with the difference decreasing as personal involvement for the decisions decreased (p=.003).

Conclusions: These results suggest that deciding on behalf of a third-party reduces our susceptibility to context-dependent risk-taking. Moreover, decreased personal involvement enhances this effect. We suggest that Construal Level Theory and perceived psychological distance is a useful potential framework for explaining these notable self-other differences in risky decision-making.

Focusing and Intertemporal Choice

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Background: Temporal discounting is a key concept in psychology, neuroscience, and economics. Understanding temporal discounting is crucial for both companies and regulators, e.g., in the retirement-savings business. The normative model is exponential discounting. However, people's decisions are often at odds with exponential discounting. An example is the so-called "annuity puzzle." It describes the phenomenon that most people choose a lump-sum payment over a rent that is paid periodically for the rest of their lives ("annuity") even though the rent has, on average, a substantially higher present value. Importantly, many other choices are similar in the sense that future payoffs are spread out over time—e.g., the benefits of not smoking or of working out. A recent theoretical model (Kőszegi & Szeidl, *Q. J. Econ.*, 2013) posits that decision makers attach "focus weights" to the payoffs incorporated in each choice option, and these weights are lower for payoffs that are spread over time than for payoffs that are concentrated on a few dates, making spread-out payoffs less attractive.

Method: We investigated whether spreading payoffs over several days influences subjects' decisions in line with the "focusing" model. 44 subjects made 25 choices each: they indicated by picking one of 10 alternatives per decision how willing they were to postpone payment in exchange for increases in the payment. All payments were made in the form of pre-dated money transfers to subjects' bank accounts. There were three conditions: "concentrated," i.e., each payment is transferred on a given day (e.g., ranging from €33 today to €42 in 5 months); "increasingly dispersed," i.e., the farther the payoff in the future, the greater it is, but the more spread it is over time (e.g., ranging from €33 today to 10 × €4.20 over the course of 3 weeks, with the final payment in 5 months); and "decreasingly dispersed," i.e., the farther the payoff in the future, the greater and the less spread out it is. The payoffs' timing was such that exponential and β–δ discounting predict the dispersed options to be more attractive than the concentrated ones.

Results: Subjects chose significantly sooner options in the "increasingly dispersed" than in the "focused" condition. In the "decreasingly dispersed" condition, the average chosen payoff was significantly later than in the "concentrated" (and the "increasingly dispersed") condition.

Conclusion: The former finding is at odds with exponential and β–δ discounting. Both findings are compatible with the "focusing" model. Hence, previous lab experiments may have neglected an important channel that influences intertemporal decisions.

Manipulating parietal interhemispheric balance in value-based choice

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Objective: Recent work has shown that visual attention plays a crucial role in economic decision-making. Eye-tracking and fMRI studies have demonstrated clear correlations between fixation patterns, brain activity, and choices. Here we attempted to provide causal evidence for this relationship, by using transcranial direct current stimulation (tDCS) over known attention regions, to influence subjects' choices. In particular, we sought to verify an important prediction of the attentional drift-diffusion model (aDDM), which is that attention has more influence on choices for higher overall values of the two choice options.

Methods: We carried out an experiment in which participants performed a series of binary value-based choices involving previously rated food items. In order to observe possible effects of interhemispheric imbalance, we applied bilateral tDCS over the posterior parietal cortices (PPC) of our subjects while they performed the choice task. One group of participants received anodal stimulation over the left PPC and cathodal stimulation over the right PPC (LA-RC group), while a second group received the opposite stimulation (LC-RA group). A third group of participants received sham stimulation (Sham group). We then used the aDDM to test various hypotheses about how the tDCS stimulation might have influenced subjects' choices.

Results: Compared to the sham group, participants in LA-RC group were more likely to select the left food item as the overall value increased. The LC-RA group did not show any spatial bias in choice, but they were less accurate. As predicted by the aDDM, in all three groups we observed faster decisions as overall value increased. Additionally, this effect was increased by LC-RA stimulation. Among the simulated models, only one replicated these effects on choice bias, accuracy and reaction times. This model suggests that LA-RC stimulation decreases the perceived value of the right item, and vice-versa for the opposite stimulation.

Conclusions: Previous studies have presented evidence suggesting that when an item is unattended, only a fraction of its value is processed. This produces a choice bias for items that receive more attention. Our results suggest that PPC is involved in this discounting of unattended items, and that the discount factor can be causally manipulated using brain stimulation. This results in spatially biased and/or less accurate choices.

fMRI reveals temporal dynamics of movie trailer viewing and choice

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Objective: A number of recent publications have demonstrated that fMRI is able to add to the predictive value of conventional methods for predicting individual choice and group purchasing behavior in response to advertising (e.g. Falk, Berkman et al. 2010; Chua, Ho et al. 2011; Berns and Moore 2012). Yet the potential usefulness of neuroimaging is greater than just that. By tracking the activation over time of brain regions known to compute value and emotional reactions, we should be able to deliver a moment-to-moment brain response analysis of dynamic stimuli, which can subsequently be used to gain insight into the driving factors of consumer choice.

Methods: 30 participants viewed cinematic trailers of 18 movies which they had not previously seen, while undergoing fMRI scanning. We collected both stated (willingness to pay) and revealed (choose three DVDs to take home) preference measures. In addition, we obtained US Box Office results and the number of hosting cinemas in the opening week (#screens) for the 18 movies, as a measure of population choice/real-world success.

Results: In a whole brain analysis using the mean activation per trailer, we find that precuneus activity correlates with individual willingness to pay, while ventromedial prefrontal cortex (vmPFC) correlates with Box Office per se and with Box Office corrected for #screens. The vmPFC adds predictive power to a regression model using only stated preference measures to predict Box Office/#screens. Thus, the neural response is associated with individual preference as well as commercial success in the population. Using ROIs derived from these predictive regions, we will track their signal over time to find which key moments in the trailer drive choice.

Conclusions: Here, we provide evidence that fMRI has potential to add to the existing tools of marketers to predict real-world commercial success, and to gain insight into the driving factors of persuasive communications. By investigating the timecourse of the areas predictive of choice, we are able to pinpoint those scenes in the trailers that are most strongly related to (population) choice.

References:

Berns, G. S. and S. E. Moore (2012). "A neural predictor of cultural popularity." Journal of Consumer Psychology **22**(1): 154-160.

Chua, H. F., S. S. Ho, et al. (2011). "Self-related neural response to tailored smoking-cessation messages predicts quitting." Nature Neuroscience **14**(4): 426-427.

Falk, E. B., E. T. Berkman, et al. (2010). "Predicting Persuasion-Induced Behavior Change from the Brain." Journal of Neuroscience **30**(25): 8421-8424.

Reaction-Time and Pupil Size Predict Changes in Preference in Intertemporal Choice

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Objective:
Much prior work in intertemporal choice models series of binary choice responses as *independent* decisions. The assumption of independence implies that responses are exclusively decision output, not input. However, as has been shown in other areas of decision-making (Xue et al, 2010), it is possible that decisions on any given trial may be affected by preceding decisions. In this pair of studies, we attempt to bring to light dynamic processes in intertemporal choice, focusing on switching (between smaller-sooner and larger-later) across consecutive trials.
Methods:
Studies 1 and 2 both included blocks of trials in which more immediate and delayed alternatives were individualized to be similarly attractive. Brain activity was recorded in Study 1 (though not analyzed at the time of this abstract submission) and pupil dilation was recorded in Study 2. Pupil dilation has been linked to norepinephrine activity, and related to both cognitive effort and response switching.
Results:
We observed slightly less switching across consecutive trials than expected given the assumption of trial independence (significant in Study 2). More importantly, in both studies, switching was predicted by longer reaction time on the previous trial. Additionally, in Study 2, we observed that switching was simultaneously negatively predicted by pupil dilation (relative to baseline).
Discussion:
Prior work establishes response slowing when alternatives are similarly attractive. Here we suggest that when the unchosen option is highly attractive (evidenced by long RT) preference was biased towards that unselected alternative on the next trial (similar to the pattern observed in risk preference, and linked to activity of the anterior insula; Xue et al, 2010). The association between switching and pupil constriction is consistent with Adaptive Gain Theory, whereby increased phasic norepinephrine output (evidenced by pupil dilation) potentiates exploitation (here continuing to choose the same type of option). Taken together, the data suggests that decision output functions also as input, accounting for previously unexplained variance in intertemporal choice behavior.

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Gains Before Losses? The Precedence of Global Features Directs Value-Based Decisions.

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Objective:

How do perceptual features influence risk-taking behavior? Is there an interaction between numerical percepts and value based choices? Based on Navon's (1977) global precedence effect (faster responses to global compared to local visual features) we examined the interaction between numbers' numerical size, the distance between them and global/local visual features. We hypothesized that a number presented at a global level will be perceived as larger and more valuable compared to when it is presented at a local level and hence influence choices.

Methods:

We developed a behavioral paradigm based on Navon's figure that included congruent and incongruent pairs of numbers instead of letters (e.g., congruent pair - a large number 9 composed out of many small number 2s; incongruent pair - vice versa). In the first session, subjects (N=32) saw a series of these modified figures and had to decide which number was larger: the local or the global number. From this we examined the interaction between numbers' numerical size, the distance between them and global/local features. A week later, subjects saw the same figures, however, they now represented a 50-50 chance of winning or losing some amount of money. Subjects had to decide whether to accept or reject the offer. The amount of money of the gain and the loss was introduced as the global and local features of the numerical figure. In some blocks, gains were presented at the global level and losses at the local level (global gain local loss - GGLL), while in other blocks the presentation was the opposite (GLLG). We compared subjects' risk-preferences between these conditions.

Results:

In the 1st session we found that as the distance between the numbers increased the improvement in RTs and error rates was larger in congruent compared to incongruent trials. In the 2nd session, for prospects with a positive expected value (EV) the probability to accept the gamble was higher when the global feature was a gain (GGLL) compared to when it was a loss (GLLG). This pattern was reversed for negative EVs. Furthermore, in the GGLL condition we found an association between EV and RT, similar to the one observed in the numerical-perceptual task of the 1st session. Finally, RTs from the numerical task (1st session) correlated with actual choices and RTs in the GGLL condition of the 2nd session.

Conclusions:

These results demonstrate important interactions between perceptual, numerical, and value systems. We suggest that the value of an economic choice option is influenced not just by its monetary value and winning probability but also by basic perceptual features such as global/local levels and numerical features such as distance and congruency.

The value of neural measures in evaluating the quality of advertisements

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Objective: Advertising is an important means through which companies can convey to consumers what they have to offer and why a product should be worth buying. In order to effectively communicate what a company is offering, it is important that an advertisement both stands out and is appreciated. Conventional marketing research techniques that are used to obtain information about the preferences of consumers typically consist of preference questionnaires and focus groups, but nowadays the use of relatively small 'neural focus groups' is becoming more and more common. In the present study, we investigated whether neural activity of a small group of people can predict consumers' attitude towards advertisements in the population at large.

Methods: The stimulus set consisted of 150 print advertisements, from five product categories: cars, gadgets, food, beauty, and fashion. Each category contained 30 advertisements. Only females were exposed to the ads from the beauty and fashion category, and only males to the ads from the cars and gadgets category. Both males and females saw the ads from the food category. A panel of 1260 people (650 females) rated notability of the ad (5-point scale), attitude towards the ad (multiple items measured on a 5-point scale), and overall liking of the ad (10-point scale). Each individual rated a random sample of 10 advertisements on all items, which resulted in each advertisement being rated by approximately 80 people. In addition, brain activity was measured using EEG in response to viewing the print advertisements for an additional group of 31 people (16 females).

Results: We found that neural activity over fronto-central electrodes in our neural focus group was strongly associated with the quality of the ad, as evaluated by the population sample. Most strikingly, we found that the brain differentiates between high and low quality ads extremely quickly at approximately 350ms after ad presentation.

Conclusion: These results suggest that neural measures from a relatively small sample may provide valuable insights into what makes advertisements attractive to consumers. Neural measures may thus provide a means for pre-testing advertisements.

Intracranial high frequency activity reveals distributed representations of reward prediction error in the human cortex and medial temporal lobe

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Objective: Reinforcement learning theory suggest that individuals alter their decisions based on reward prediction errors (RPEs). Whereas functional neuroimaging studies have demonstrated neural representations of RPE in a confined set of brain regions that receive prominent inputs from midbrain dopamine neurons (Rutledge et al., 2010), we hypothesized that RPEs are more widely represented in the human brain, as suggested by monkey single-unit studies (Wallis and Kennerley, 2011). Functional neuroimaging studies typically average activity within regions may not detect heterogeneous representations of RPEs that may exist in several neural populations throughout the brain. We hypothesized that by using methods that are sensitive to heterogeneous encoding patterns, one may identify widely distributed neural representations of RPE.

Methods: High frequency activity (HFA, 70-200 Hz) in intracranial electroencephalography (iEEG) recordings is an established indicator of local firing rates (Manning et al., 2009) and can be studied at individual electrode contacts to detect heterogeneous patterns of neural activity within a region (Bouchard et al., 2013). We obtained iEEG recordings from 39 patients undergoing surgical monitoring for drug-refractory epilepsy as they performed a two-alternative reinforcement learning task. We identified putative RPE signals as electrode contacts whose activity distinguished between positive and negative outcomes, and was also modulated by reward expectation (estimated by fitting a reinforcement learning model to subjects' behavior).

Results: We found that putative RPEs were widely distributed throughout the brain, including occipital, temporal, and parietal regions, where they have rarely been identified by neuroimaging studies. HFA patterns that were consistent with positive RPEs were functionally related to learning; the strength of their post-reward expectation-related differences was correlated with subjects' tendency to select the high-probability item during the task. These results suggest that behaviorally-relevant representations of RPE are widely represented throughout the human brain

Conclusions: These results suggest that behaviorally-relevant representations of RPE are widely represented throughout the human brain

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References:

Manning, J. R., Jacobs, J., Fried, I., and Kahana, M. J. (2009). Broadband shifts in LFP power spectra are correlated with single-neuron spiking in humans. Journal of Neuroscience , 29(43):13613 – 13620.

Rutledge, R., Dean, M., Caplin, A., and Glimcher, P. (2010). Testing the reward prediction error hypothesis with an axiomatic model. Journal of Neuroscience , 30(40):13525–13536.

Wallis, J. D. and Kennerley, S. (2011). Contrasting roles of reward signals in the orbitofrontal and anterior cingulate cortex. Annals of the New York Academy of Sciences , 1239:33–42.

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Expected, not experienced, affective outcomes predict loss aversion.

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Stemming from behavioral economics, it is widely accepted that most of us are loss averse because we experience the negative consequences of a loss to a greater extent than the positive consequences of a gain. But can loss aversion in choice be reliably predicted by how we actually feel when we experience losses and gains? Surprisingly, this central assumption of Prospect Theory has never been tested. To answer this question, we developed a novel paradigm where participants evaluated how they felt directly after experiencing different gains and losses, how they expected to feel should they experience these outcomes, and made choices between gambles involving these potential gains and losses. We found that loss aversion, as indicated by gamble choices, was mainly predicted by how people expected to feel should they experience monetary losses or gains, rather than by how they felt directly after experiencing them. We conclude that how people actually feel when they experience a gain or a loss cannot reliably predict how they will make a decision involving these potential outcomes in the future. Instead, we suggest that they decide based on how they expect to feel, rather than on their previous experience.

Brain responses related to the effectiveness of advertising execution style

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Objective: We aim to contribute to the evolving literature on how a 'neural focus group' may help in testing and optimizing advertising by demonstrating how the brain activity of a relatively small group of individuals (i.e., using functional magnetic resonance imaging (fMRI)) relates to market level responses to television commercials. Moreover, comparing a unique set of eleven different ads for the same brand and product enabled us to investigate the influence of advertisement execution style, in terms of its functional and experiential elements and its innovativeness, on advertisement effectiveness. That is, the selected commercials were of comparable professional quality, equal length and contained a highly similar voice-over text, but differed in their specific execution style.

Methods: We combined data from three independent samples: a neural focus group (N = 24) and a large sample of consumers in the population (N = 1239) to relate the brain responses to advertising effectiveness, and a sample of advertising experts (N = 9) to be able to link the observed brain activity to the commercial execution style. Participants in our fMRI study passively viewed each commercial four times in random order, and filled out a self-report questionnaire afterwards outside the scanner. Participants in the large sample were randomly assigned to view one of the eleven commercials in an online survey. Advertising effectiveness was measured by their online information search behavior in direct response to the commercial (i.e., click-through rate to the brands' website). The expert panel viewed each commercial in random order and rated the objective characteristics of the commercial execution.

Results: Our findings show that neural activity in the left inferior temporal gyrus (ITG) was related to out-of-sample click-through rate. Moreover, the activity in this region was stronger when experiential sensory elements (such as exciting visuals and music) were more prominent in the commercials, which corresponds with the known involvement of the ITG in the integration of visual and auditory information for a comprehensive sensory experience.

Conclusions: Hence, our results suggest that 1) we can relate variability in market level behavioral responses to a set of television commercials to the brain activity that is evoked by these commercials in our neural focus group; 2) brain activity is associated with out-of-sample advertising effectiveness even when we control for self-reported purchase intent; and 3) using the observed brain activity, we can identify which advertising execution element drives effectiveness within this set of commercials.

Do different types of decision difficulty have a common neural correlate?

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Objective: The subjective experience of difficulty can feel similar across many different decision contexts, but it is unknown whether this similarity in experience is accompanied by a neural signal that is common to different forms of decision difficulty. Regions in a fronto-parietal network have been implicated in detecting subjective difficulty and responding to many different forms of cognitive demand. However, previous studies have typically used a single manipulation of cognitive demand and also have not dissociated cognitive demand from time on task. This study aims to address these limitations with a cognitive conjunctive design across multiple kinds of decision difficulty.

Methods: We measured BOLD signal during a well-studied delay discounting task, with four different manipulations to induce increased difficulty: 1) time pressure, 2) more options, 3) disfluency, and 4) options close in subjective value. Easy control trials did not induce time pressure and involved only two options presented numerically that were far apart in subjective value. Trials were blocked and after each block subjects rated how difficult they thought the last set of decisions were.

Results: Subjects spent significantly more time on hard trials than on control trials for the disfluency, 4-options, and close in value manipulations and spent significantly less time on hard trials than on control trials for the time pressure manipulation. All four of the manipulation blocks were rated as significantly more difficult than the easy control blocks. Critically, during our time pressure manipulation, subjects spent less time on hard trials while still rating these trials to be more difficult than control trials. Not surprisingly, unique activity was found in left inferior frontal regions for disfluency and early visual regions for increased number of options. We also found widespread activation in fronto-parietal regions for all manipulations. Surprisingly, however, we did not find a common frontal region of increased activation that was reliable across all four manipulations, and only found a small overlapping area in parietal cortex.

Conclusion: These results suggest that, while all forms of decision difficulty and cognitive demand are generally associated with greater activation in fronto-parietal regions, these activations in response to cognitive demand may not overlap at a more fine-grained level.

The attentional Drift Diffusion Model with larger choice sets

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Objective

Krajbich et. al. (2011) showed that the Attentional Drift Diffusion Model (aDDM), by utilizing fixation data as a proxy for momentary attention, can greatly improve choice predictions and approximation of psychophysical data over standard versions of the DDM for binary and trinary choices. Interestingly, the authors demonstrated that the set of optimal parameters for binary choices approximately holds for trinary choices as well. We propose a natural extension to this line of research, with several goals in mind. First, we are interested in the general applicability of the aDDM to larger choice sets (sizes = 4, 6, 8). Second, we want to investigate the extent to which the aDDM parameters stay stable as the set size increases. Third, we want to investigate whether personal traits, such as working memory capacity and impulsivity, can explain parameter shifts and/or break-down of the aDDM as the set size increases

Methods

We extend the experimental paradigm used in Krajbich et. Al. (2011). 22 subjects are asked to make food choices from choice screens of four, six and eight items, while we monitor their attention with eye-tracking. They also complete a n-back task and questionnaires that enable us to extract measurements of working memory and impulsivity.

Results

We find that multiple key predictions of the aDDM, are borne out in our data for all set sizes. For example, last fixations are shorter than equivalent middle fixations, which is explained by a crossing of the decision boundary during the last fixations and therefore terminating it prematurely. As another example, there is a choice bias towards the last item attended and a bias towards choosing items that are attended longer during a trial. The poster will also discuss preliminary fittings of the aDDM to this dataset.

Acknowledgements

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Emotional arousal to future monetary rewards predicts choice

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Objective: People tend to prefer immediate rewards to rewards received after a delay, even when the delayed reward is larger (this is known as temporal discounting). These suboptimal preferences for immediate rewards may be driven by the fact that immediate rewards can be imagined more vividly, while delayed rewards are usually construed as more abstract, and it is more difficult to predict and imagine future emotional states. Indeed, manipulating the mental representation of a future reward to make it more vivid changes its emotional intensity, and makes people more likely to choose it. Although it has been suggested that the influence of prospection on choice is mediated by emotion, this has never been shown using an objective measure of emotional arousal.

Methods: Individuals chose between immediate and delayed rewards while pupil dilation responses were measured. Pupil dilation is a well-established correlate of sympathetic nervous system activity in response to emotional stimuli. To manipulate the concreteness of the delayed reward, we presented it either with the date on which it would be received (e.g., "$30 on May 3"; DATE condition) or in terms of the delay to receiving it (e.g., "$30 in 30 days; DAYS condition). Past studies have suggested that seeing the date on which a delayed reward would be received will make the delayed reward more concrete. Each participant faced the same set of choices in the two different conditions (trials were randomly interleaved). In order to characterize emotional responses to these delayed rewards specifically, options were presented sequentially (immediate reward first, delayed reward second).

Results: Although the same choices were shown in both conditions, individuals exhibited different discount rates in the two conditions. A subgroup of subjects (N = 27) was more patient in the DATE condition, while another subgroup (N = 24) was more likely to choose future rewards in the DAYS condition. Critically, participants who preferred the rewards framed in terms of delay showed a larger emotional arousal response (i.e., more pupil dilation) to these rewards, and vice versa (subgroup x condition interaction: $F_{(3,3897)} = 7.74$; $p < 0.01$). Furthermore, the degree to which participants were more patient in the DATE vs. DAYS condition was correlated with the difference in pupil dilation responses between these conditions ($r = 0.36$; $p < 0.01$). Finally, pupil dilation during presentation of the future reward correlated with the subjective value of the delayed reward (as determined by the hyperbolic model; $\beta = 8.79$; $p < 0.001$) and predicted choice of delayed reward (Coeff. = 1.42; $p < 0.001$).

Conclusions: We found that emotional arousal increases with the subjective value of future rewards. This emotional arousal response can be enhanced, and people can become more patient, if we frame future rewards in a way that the individual finds more concrete (e.g., in terms of DATE or DAYS). These results add to our understanding of the role of emotion in intertemporal choice.

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Neural evidence of prospective evaluation predicts model-based choice

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Objective:
Decisions may arise retrospectively, such as by reinforcement, or prospectively by considering their likely consequences using a learned map or model. Although human and animal choices sometimes reflect knowledge of their consequences, there is little evidence whether this actually arises from prospective evaluation. We tested whether such evidence could be observed in the human brain.

Methods:
Twenty subjects completed a sequential reward-learning task designed to distinguish model-based (prospective) from model-free (retrospective) approaches to decision-making, while being scanned with fMRI. Subjects navigated to terminal task states from two different, randomly determined starting states in search of monetary reward. Though visually different, these starting states were functionally equivalent in that each afforded identical transitions to terminal task states. The states in this task were represented by different classes of stimuli known to recruit distinct regions of visual cortex. This feature permitted us to ask whether evidence of future paths in the task could be observed at the time of choice.

Results:
To assess the relationship of prospective evaluation and behavior, we correlated two quantities estimated for each subject: evidence of prospective BOLD activation at choice time, and the degree to which choices were consistent with model-based vs model-free strategy. Consistent with the view that model-based choice relies on prospective planning, we observed a positive correlation between these quantities across subjects.

A prospective account further predicts that the necessary planning operation for model-based decision-making is identical across the visually different but functionally equivalent starting states in the task. Hence, such a strategy should incur minimal switch costs as task start states change from trial to trial. Consistent with this prediction, the observed recruitment of additional neural resources during changes of starting state correlated negatively with model-based behavior.

Conclusions:
These results directly support the widespread supposition that model-based preferences are computed via prospective evaluation at the time of choice.

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Dopamine D2-receptor blockage stabilizes orbitofrontal reward representations

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Objective: Prefrontal reward representations are critical for goal-directed behavior. The stability of prefrontal representations has been suggested to be modulated by dopamine. A current two-state model suggests that the stability of prefrontal network representations depends on the ratio of D1/D2 receptor activation. A D2-dominated state would allow for multiple but weak representations, whereas a D1-dominated state would favor few but stable representations.

Methods: Here, we tested this model in the context of reward representations in the human orbitofrontal cortex (OFC) using dopamine receptor-specific pharmacology and multivoxel pattern-based functional magnetic resonance imaging (fMRI). Before performing a non-instrumental outcome-prediction task, human subjects received either 400 mg of the D2-receptor antagonist amisulpride (N = 27) or a placebo (N = 24) in a double-blind fashion.

Results: Behavior did not differ between groups, allowing a comparison of neural reward representations independent of potentially confounding differences in behavior. Using a searchlight decoding approach, we estimated the strength of reward representations in the OFC. In line with the model, we found that dopamine D2-receptor blockage significantly ($p < 0.05$, FWE whole brain corrected) strengthened distributed reward representations in the medial OFC. Moreover, we found a significant ($p < 0.05$, FWE whole brain corrected) dose-dependent increase in functional connectivity between the medial OFC and the inferior parietal sulcus (IPS), suggesting that dopamine stabilizes prefrontal network representations by enhancing frontoparietal coupling.

Conclusions: Our results show that dopamine D2 activation stabilizes prefrontal representations and are in line with the idea that dopamine gates the afferent input to the prefrontal cortex, thereby facilitating robust network representations.

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Distinct neural computations mediating observational learning derived from facial expressions versus verbal feedback

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We often learn about the value of actions not through doing them ourselves, but through watching other people do them and observing the outcomes they experience. Relatively little is known about the neural computations that support vicarious observational learning. A major open question is how does the source of information being observed influence observational learning: e.g. is learning through observing others' affective reactions different from through verbal feedback? To address this question we used a task that assessed observational learning, using conditions in which information was conveyed about others' experienced outcomes with facial expressions, words, or both.

fMRI participants (observers, N=25) learned about the likelihood that 6 lottery machines would deliver aversive (salty tea) or neutral (artificial saliva) outcomes by watching videos of 3 observees play the lotteries. Each observee was associated with a pair of lotteries and 1 of 3 interleaved conditions. The conditions were: 1) Face Only (FO), observers saw videos of observees receiving outcomes paired with a nonsense word. 2) Word Only (WO), observers saw videos of observees in which their face conveyed no expressive feedback, paired with words indicating the experienced outcome. 3) Face+Word (FW), observers saw both expressions and words depicting the experienced outcome. Lottery pairs contained one aversive ($p_{aversive}$=0.8, $p_{neutral}$=0.2) and one neutral ($p_{aversive}$=0.2, $p_{neutral}$=0.8) lottery. Lottery pair contingencies reversed randomly once during the experiment. To assess learning, observers completed randomly interspersed choice trials in which they chose between lottery pairs. Choice feedback was delivered between runs and without choice information.

Behavioral data were fit with a modified SARSA reinforcement-learning model. Accuracy was significantly above chance in all conditions ($p<0.005$) and significantly higher in the FW ($p<0.005$) than in the FO and WO conditions. Learning rates were also higher in the FW (0.51) than in the FO (0.37) and WO (0.38) conditions, though this difference was not significant. fMRI analysis revealed signals in the amygdala and face-selective temporal/occipital cortex correlated with aversive prediction error (i.e. highest for unexpected aversive outcomes) in conditions where face expressions depicted outcomes (FO & FW). Conversely, fMRI signal in part of the caudate head correlated with appetitive prediction error in conditions in which words described outcomes (WO & FW). These data suggest that learning through observation on the basis of social and non-social feedback may depend on at least partly distinct neural substrates.

Distinct Reward Properties are Encoded via Interactions between Ventral Striatum and Dorsolateral Prefrontal Cortex

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Introduction: Deficits in reward processing manifest in diverse psychopathologies, particularly depression. Individuals suffering from depression exhibit blunted striatal responses to rewards. Yet, understanding the link between altered reward circuitry and depression presents a significant challenge because rewards are composed of multiple properties. Notably, affective properties modulate emotional experience while informative properties signal how to adapt behavior to maximize future rewards. Affective and informative reward properties are often conflated, making it difficult to examine how distinct reward properties are encoded by the striatum and interconnected reward circuitry.

Methods: We approached this problem by creating a paradigm that emphasizes a specific reward property (affective or informative) within two independent guessing games. On each trial of the Affective Card Task (ACT), subjects (n = 33) chose between three decks of cards that yielded variable levels of points (1, 2, and 3). The Informative Card Task (ICT) employed a similar structure except subjects received letters (D, K, and X) that appeared with different probabilities in each deck (50%, 33%, and 17%). We instructed subjects that earning enough points in the ACT would allow them to play another task for monetary bonus at the conclusion of the experiment; however, earning this bonus money would require using information learned in the ICT. We also measured individual differences in depressive symptoms using the Beck Depression Inventory.

Results: Our results indicated that prediction errors for affective and informative reward properties are encoded within the ventral striatum. Although ventral striatum exhibited similar activation levels for both reward properties, we predicted that functional connectivity with striatum would distinguish affective and informative reward properties. To test this hypothesize, we conducted a psychophysical interaction analysis using ventral striatum as the seed region. We found that distinct reward properties are encoded via idiosyncratic interactions between ventral striatum and dorsolateral prefrontal cortex. Specifically, individuals with fewer depressive symptoms exhibited increased connectivity for affective relative to informative reward properties; in contrast; individuals with more depressive symptoms exhibited increased connectivity for informative relative to affective reward properties.

Conclusions: Our findings suggest that functional connectivity with ventral striatum dissociates affective and informative reward properties according to individual differences in depressive symptoms. Identifying the mechanisms supporting distinct reward properties—particularly as a function of depressive symptomology—could potentially advance translational models of psychopathologies marked by reward processing deficits.

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Stress increases taste focus, but these hedonic signals can be overcome

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Objective: We often need to integrate short and long-term aspects in order to assess whether a specific choice corresponds to our overall goals. Previous evidence shows that both social factors and stress may influence this type of computation. Little is known, however, about the underlying neural mechanisms of these effects. Here, we used the Socially Evaluated Cold Pressor Test to stress subjects and subsequently examined choice behavior and neural activity with BOLD fMRI.

Methods: Participants (n = 51) were presented with two foods and asked to choose the healthier item whenever possible. We also provided visual recommendations for the healthier option in the majority of cases. At the end of the session one randomly selected choice was implemented.

Results: The Stress group differed from Controls in stress ratings, hormone levels, choice behavior, and neural activity. A mixed effects logistic regression showed that the Stress group put more weight on the taste of the items. In addition, participants with higher self-reported stress levels were less likely to choose the healthier food as H_{diff} increased and more likely to fail in self-control as T_{diff} increased. Healthy recommendations had less impact on improving self-control in participants with higher stress levels.

At the neural level, the ventromedial prefrontal cortex (vmPFC) represented an overall food value, incorporating weighted taste and health aspects in both groups. However, the amygdalae and ventral striatum showed a stronger representation of taste values in the Stress compared to Control group, and a psychophysiological interaction analysis (PPI) showed that activity levels in these regions were more correlated with vmPFC activity when stressed subjects chose the tastier food.

Both groups were able to overcome misleading recommendations, recruiting a network of left dorsolateral prefrontal cortex (dlPFC), dorsal ACC, and superior parietal lobule. A PPI analysis revealed that connectivity between left dlPFC and vmPFC changed as a function of perceived stress level. Subjects with higher self-reported stress levels had less robust connectivity between dlPFC and vmPFC when selecting healthy food items.

Conclusions: Acute stress results in a greater impact of immediately rewarding taste factors on self-control choices. These changes in the relative weighting of taste and health factors in decision-making are associated with increased taste signaling in the ventral striatum and amygdalae as well as differences in connectivity between value coding regions in vmPFC and both limbic and dlPFC regions. Thus, acute stress appears to influence value computations by altering the interactions between vmPFC and limbic and dlPFC regions.

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Improvements in learning from high-variance outcome patterns from childhood to adulthood relate to increases in risk-taking behavior

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Objective: Risk-taking behavior increases dramatically from childhood to adolescence. Previous research has suggested that this phenomenon is partially driven by a peak in neural prediction error response to reward during adolescence. However, naturalistic public health relevant risks often have a particular high-variance feedback structure, with frequent small rewards coupled with rare but very large costs. Given this pattern, we examined how the ability to learn to evaluate risks with high-variance and low-variance outcome structures changes from childhood to adulthood.

Methods: Sixty subjects between age 8 and 30 performed a learning task in the scanner in which they made choices about four different "point machines," which varied on expected value (positive or negative) and outcome variance (high or low). To examine differences in sensitivity to the range of magnitudes seen on the high-variance machines, we fit each subject's choice data to a prediction error model modified to include an additional parameter reflecting the concavity of the value function. Prediction error response to trial outcomes derived from each individual's model parameters were then used as regressors on the imaging data. In addition, outside of the scanner all subjects completed the Balloon Analog Risk Task (BART), a laboratory measure shown to correlate well with public health relevant risk-taking behaviors, and the Weschler Abbreviated Scale of Intelligence (WASI).

Results: The value function concavity factor correlated significantly with age, with younger subjects showing a greater tendency to underweight large values. The concavity of the value function also correlated with BART performance, even after accounting for both age and IQ effects. Using values derived from the prediction error model modified to reflect individual differences in value scaling, prediction error patterns of response to positive feedback was seen in both the striatum and medial frontal cortex, while prediction error response to negative feedback was seen in the anterior insula.

Conclusions: These findings suggest that differences in sensitivity to value magnitude, as reflected in changes in value function concavity, may partially explain the increase in risk-taking behavior seen as children move into adolescence. The neuroimaging results, which show robust prediction error responses after adjusting for individual differences in value scaling, suggest that the changes in sensitivity to value magnitude seen in the behavioral data may be due to developmental changes in the scaling of neural prediction error responses.

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Title:
Contextual control of option value during learning

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Abstract (139/150)
Context-dependency of option values has been studied in adaptive coding and range-adaptation. Here we show, using a novel behavioral design, that value contextualization is deployed in punishment avoidance. This adaptive function is traded against the acquisition of potentially suboptimal preferences. Both effects (adaptive and maladaptive) were well accounted by a novel learning model, which bridges antagonist 'value-first' and 'comparison-first' approaches to decision making. The specific computational construct was represented in the lateral (dorsal and polar) prefrontal system, whereas a medial system (ventral and dorsal) appeared to be limited to decision value encoding. Neural data also show that contextualization of option value promotes neural efficiency, limiting the need for a punishment opponent learning system. This last observation conciliates wealth of pervious inconsistent findings, advocating similitude or difference between the reward and punishment learning neural systems.

Keywords: context dependence, decision-making, reinforcement learning, counterfactual learning, reward, punishment, prefrontal cortex, striatum, insula

Neural correlates of hierarchical latent inference: a computational fMRI study.

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Objective: Knowledge of the state of latent variables in an environment is crucial for good decision-making. These latent states must be inferred from observable, conditionally related, signals. We aimed to clarify two important issues regarding this inference process in a computational fMRI study: First, given the complexity of hierarchical inference, do humans trade accuracy for efficiency by using state-space simplification strategies? Is this trade-off sensitive to environment dynamics? Secondly, what systems underpin the updating of latent variables in the brain?

Methods: Subjects (n=22) performed a three-dimensional latent state estimation task with two conditions which differed based on whether or not switches occurred. We hypothesized that this environmental feature would bias subjects to use distinct learning strategies, which differed based on the state-space over which they updated and made choices. More specifically, a threshold parameter was introduced and latent states with posterior probabilities which fell below this threshold were removed from the state-space. Behavioral parameters in this model (and a variety of alternatives) were estimated hierarchically based on MCMC sampling. The negative entropy (NE, measuring information accumulation) of the prior/posterior distributions and the divergence between prior and posterior (BPE, "Bayesian prediction error") were estimated in a general linear model as parametric modulators time-locked to corresponding task events. This was done for both the observable and latent distributions in the hierarchy.

Results: Bayesian model comparison implicated the belief thresholding mechanism across conditions and indicated that there was a significant difference in the threshold parameter values between conditions ($p=0.00014$, paired t-test) with significantly higher thresholds used in the NOSWITCH condition. Neurally, NE(prior) and BPEs for observable features were reflected in the activity of corresponding regions of the visual stream (e.g. V4 for color, area MT for motion, ITG for shape) while the same signals for the latent state were found in dorsolateral prefrontal cortex (dlPFC). Activity in ventromedial and dorsomedial prefrontal cortex correlated with NE(posterior) at the time of behavioral response.

Conclusions: Behavioral analyses imply that humans modulate their latent inference strategies based on context in line with accuracy/efficiency trade-offs. fMRI results show that the inference hierarchy is reflected in the brain by indicating that latent updating occurs in dlPFC while observable sensory information is accumulated in mid-level visual areas.

The Neural Computation of Subjective Moral Value

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Introduction:

The neural mechanisms underlying moral decision-making have been extensively investigated with moral dilemmas that require judgments whether if it is morally permissible to harm a smaller number of people in order to save a greater one. However, little is known about specific neuro-cognitive mechanisms that can explain why certain individuals judge harming the smaller group morally wrong while others judge it to be appropriate or even mandatory.

In the present project, we approach this issue from the perspective of the value that participants place on each of the lives under consideration. Computations of values for choice options play a crucial role in many other forms of decision-making (e.g., economic), and recent studies have proposed that comparable neural value representations may also underlie moral decisions (Shenhav & Greene, 2010).

Methods:

The moral task required participants to solve a dilemma similar to the classic footbridge dilemma: Should they sacrifice the life of one person in order to save several other people? In order to calculate subjective moral values, we manipulated two factors in the dilemma from trial to trial: The number of people (min =1, max = 10) that could be saved and the moral deservingness (criminal record; from none to mass murder) of the person that would need to be sacrificed. This latter factor allowed us to identify how much each participant "discounted" the moral value of a person's life based on his criminal record, in close resemblance to the well-known temporal discounting of monetary values. In the matched economic paradigm, we estimated participants' subjective monetary value in a standard temporal discounting task.

Results:

Subjective moral value computations correlated strongly with activity in the right TPJ (peak at 45 -22 2; $T = 4.76$, $p < 0.001$): The higher the trial-wise subjective value of the life to be sacrificed, the higher the activation in this area. In contrast subjective monetary value correlated with BOLD activity in the vMPFC (peak at 0 29 4; $T = 4.46$, $p < 0.001$). Direct comparisons of the value-related BOLD signals during both tasks confirmed that the rTPJ was more strongly involved in the computation of subjective moral values, whereas the right DLPFC (peak at 48 29 37; $T = 3.96$, $p < 0.001$) showed stronger correlation with monetary values.

Interpretation:

Our study provides the first evidence that the TPJ is involved in computing subjective moral values that – like other value signals – relate to individual preferences and take into account value discounting by contextual variables. These moral values computations are clearly domain-specific, as they are spatially dissociated from computations of monetary values under comparable choice situations.

References:

Shenhav, A. & Greene, J. D. (2010) Moral Judgments Recruit Domain-General Valuation Mechanisms to Integrate Representations of Probability and Magnitude. Neuron, 67, 667-677.

Valuation bias: the neural mechanism of free-product valuation

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Objective: Economic models assume that our decisions are guided by their expected utility. However, in real life people often behave differently. Here we focus on a special case: the valuation of free products. It has been shown that given a choice between a zero-priced product and a slightly more valued product for an almost zero price, people prefer the zero-priced product (Shampanier, Mazar & Ariely, 2007). We investigate whether zero-priced products are indeed chosen more often than equally valued alternatives, and additionally study the neural mechanisms underlying this bias.

Methods: We conducted two studies: a behavioural one and an fMRI one. In the behavioural study we had forty students (11 males) who first did a behavioural task to estimate their willingness to pay (WTP) for each of 140 common consumer goods. Based on these WTPs we constructed binary pairs of stimuli: a "preferred" product (slightly higher WTP) and a "target". This was done to ensure there is no preference for the target product. Next, they did a Choice Task: on each trial, participants simply chose between these two items. We manipulated the prices by discounting both by the same amount, such that the target was presented at each of the four prices: €0, €3, €6 and +€3 with the "preferred" product correspondingly more expensive. The last condition (+€3) meant that if that product was chosen, the participant received the product, plus an additional €3. The task was fully incentivized: out of 120 choices one was randomly selected and played out.
For the fMRI study we are using the same paradigm: first assessing the WTP for each of 225 consumer goods, and using them to construct the binary pairs for the Choice Task. However, we are presenting the target at five prices: €0, €2, €4, €6 and +€2 with the "preferred" product correspondingly more expensive, with a total of 150 trials.

Results: For the behavioural experiment we find that, while for the €3 and €6 conditions participants were relatively indifferent between the products, in the €0 condition participants preferred the target item significantly more than chance. Interestingly, there was no significant increase in choices for the target in the +€3 condition compared to the €0 condition. This indicates that choices were not driven by the goal of ending up with the maximal amount of money. Using fMRI we will study the potential mechanisms involved in the increased value associated with free products. Specifically, we are interested whether this increase is driven by an exaggerated decrease in the pain of paying for the free product or by an overweighting of the benefits associated with the free product.

Conclusions: We show a choice bias for free products. To gain more insight into the underlying mechanism driving this bias in valuation, we are currently running this study using fMRI.

Mechanisms of choice behavior shift using cue-approach training

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Objective: To further examine the underlying mechanisms of the cue approach effect by conducting behavioral variants of the task.

Methods: Participants perform an auction to determine their willingness-to-pay (WTP) for 60 junk food items. The latter are split into High (HV) and Low Value (LV) items. During original cue-approach training, participants press a button when they hear a tone that is presented on average 750ms after the onset of the food stimulus (which disappears after 1s). During a subsequent probe, participants chose for consumption between pairs of items with similar WTP: one item previously associated with the cued button press (GO) and one that was not (NOGO). Replicated results show that participants consistently choose GO over NOGO items but only for HV choice pairs.
Press only in block: 21 participants (15 F, mean age 21.2 ± 2.3) completed a study to determine if a button press without a cue is sufficient to induce the same effect. They were instructed that 2 block types would be presented: 1) simply view items (NOGO); 2) Press a button every time an item appears on the screen (GO). No tones sounded in either block type.
Immediate cue: 25 participants (21 F, mean age 20.8 ± 2.3) completed a study to determine whether the time delay for the cue after food stimulus onset is necessary to induce the effect. In this version the cue to press a button was presented together with the onset of the food item with no delay.
Choose with eyes: 25 participants (15 F, mean age 21.4 ± 2.8) completed a study to determine whether using a different effector during probe (eye vs. hand) following regular cue-approach training will yield the same effect. At probe, participants used their eyes to fixate on the item they would like to choose for 750ms rather than press one of two buttons to indicate their choice.

Results: **Press only:** *No effect on preference*. Participants chose the GO over NOGO item on 47.7% of HV and on 49.7% of LV choice trials (ns).
Immediate cue: *No effect on preference*. Participants chose GO on 54.6% of HV and on 52.1% of LV trials (ns).
Choose with eyes: *Standard cue-approach effect*. Participants used their eyes to choose GO on 62.6% ($p = 0.002$) of HV and on 59.2% ($p = 0.03$) of LV choice trials.

Conclusions: The original cue-approach findings together with our current results suggest that: 1) a non-cued motor response is not enough to induce the effect; 2) Heightened attention appears to be essential for inducing the effect; 3) The effect is not specific to the trained effector. Attentional and memory mechanisms are in play to induce the cue-approach effect.

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Do People Break Even or Learn from Experience?

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Objective: Decision makers accept higher risk bets to break even after experiencing losses. In contrast, reinforcement learning theories predict that decision makers learn to avoid gambles from which they have previously received negative outcomes. Here we examine which tendency is stronger: the need to break even or to learn from prior loss experiences.

Methods: We presented the subjects with 268 choice situations that were divided into six sequences, with an initial endowment of 1000 euro cents in each. The subjects selected between a low risk gamble (e.g. a chance to win or lose 10c), and a high risk gamble (e.g. ±55c), and the outcome of the selected gamble was added to their total earnings. Subjects did not know the exact winning (and losing) probabilities of the gambles (50% in reality). One of the six sequences was randomly selected for payment. fMRI analysis was based on 21 subjects (13 female, mean age 23 years, range 19–36 years).

Results: Subjects reselected the high risk gambles significantly more often after loss experiences than after gain experiences ($p<.05$; opposite but non-significant pattern for low risk gambles), supporting the break-even tendency. The estimate of the learning parameter was statistically significant for eleven of the twenty-one subjects ($p<.1$). We found significant activation clusters in the left and right ventral striatum for positive outcome valence ($p<.05$, FWE corr). We extracted the cluster data and found a larger difference in signal values (gain > loss) in the high risk than low risk gambles (risk level x outcome valence interaction, $p<.05$), suggesting either larger valuation difference or stronger prediction error signals for high risk than low risk gambles. We also identified the brain areas where the risk level × outcome valence interaction term was significant on a whole-brain corrected level. We found activation in an affect-related brain network consisting of bilateral anterior insula and anterior cingulate / medial prefrontal cortex.

Conclusions: Our results indicate that the urge to gain back prior losses looms larger than the need to learn from prior experiences. The striatum shows a larger difference to gain and loss outcomes in the high risk than in the low risk trials. This difference does not translate to behavior. Instead, the increase in risk appetite is associated with affective brain mechanisms which have previously been related to a stronger risk taking tendency after both gains and losses.

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Emotion Prime Effects on an Intertemporal Choice Paradigm

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Objective: Past work has indicated that emotional face primes can potentially alter intertemporal choice preferences. Our goal was to examine this with happy, fearful and neutral faces, and to assess whether norepinephrine output of the locus coeruleus (as inferred by pupilometry) was associated with observed affects of primes.

Methods: Thirty-eight subjects completed an emotional face prime intertemporal choice paradigm during collection of pupillometry data. Each subject completed 48 pseudo-randomized trials in which an emotional face prime (either happy or fearful with neutral as a control) preceded an intertemporal choice that was individualized to be a difficult (alternatives of similar delay-adjusted values). Both behavioral data, and pupillometry data were analyzed using hierarchical linear models. Pupillometry data was averaged across the half second preceding and following choice and compared with baseline to get a percent change in order to infer phasic changes in noradrenaline, and to assess their association with reaction time, condition, and choice.

Results: Presentation of both happy and fearful face primes (relative to neutral) resulted in significantly increased preference for the smaller sooner option. Indeed, for the happy face prime (though not fearful), even presentation one trial prior to the current trial was significantly associated with increased preference for the immediate alternative. Increased relative pupil dilation during decision making was associated with longer RT consistent with prior work, but did not differ by condition, and was not associated with the observed effects of emotion primes on choice.

Conclusions: These data provide more evidence that incidental emotion cues affect intertemporal choice. However, the specific pattern (both fearful and happy primes biasing choice towards the immediate alternative) diverges from our previous finding using a similar, though not identical procedure (Luo et al, 2012). Additionally, we found no support for the hypothesis that the effects of emotional face primes were linked to noradrenergic responses. Consistent with this, the fact that the effect-size observed for happy faces was greater than that observed for fearful faces suggests that the effect of emotion-primes is not a function of general arousal, since fearful faces are more arousing.

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Ventral ACC Activity Tracking Evidence of Interpersonal Similarity Facilitates Trusting Behavior

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Objective: Interpersonal similarity increases favorable attitude towards another person (Byrne 1971, 1997). Supporting the behavioral findings, a recent fMRI study showed that ventral anterior cingulate cortex (vACC) activity was associated with the positive response to vicarious reward given to a similar other (Mobbs et al., 2009). However, it still remains unclear how the vACC integrates evidence of interpersonal similarity and whether its activity is responsible for trusting behavior towards similar versus dissimilar others.

Methods: Inside the fMRI scanner, 21 participants performed a preference judgment task where each participant along with two other unfamiliar partners expressed their personal preferences by choosing between pairs of items, values, and activities. The two partners were set to a similar and a dissimilar other, whose preferences overlap with those of the participant by 70% and 30% of the total trials, respectively. After the fMRI scanning, participants also played the trust game consisting of 15 trials with varying amount of initial endowment, posing as investors with the two partners as trustees.

Results: We found that the activity of vACC increased while participants were presented with the symbols of similar compared to dissimilar partners during the preference judgment task. In addition, the vACC activity towards the similar versus dissimilar partners predicted the percentage of investment in the trust game. That is, greater activity in the vACC was associated with increased investment to the similar compared to dissimilar others (r=.44, p<0.05). To examine the neural circuitry involved in updating similarity representation encoded in the vACC, we also contrasted between the events of same versus different choices made by the partners, which revealed bilateral temporoparietal junction (TPJ). In addition, a PPI analysis using the vACC as a seed region revealed greater functional connectivity with the bilateral TPJ for the events of same compared to different choices by the partners.

Conclusions: The present study demonstrated the role of the vACC in integrating evidence of interpersonal similarity to form favorable attitude towards another person. Increase in the vACC activity was shown to facilitate trusting behavior towards a similar other, which may shed lights on the fundamental neural mechanisms underlying the similarity-attraction effect.

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Bilateral Prefrontal Transcranial Direct Current Stimulation (tDCS) Reduces Impulsivity in Intertemporal Choice

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Objective: Albeit recent progress in elucidating neural mechanisms of intertemporal choices, direct causal evidence mediating temporal discounting (TD) remains controversial. We tested the hypothesis that dorsal lateral prefrontal cortex (DLPFC) plays a causal role in TD decision. Specifically, we tested the hypothesis that excitation of the DLPFC could reduce intertemoral impulsivity.

Methods: Thirty five adult subjects participated in the three consecutive day study (right hemisphere anodal/left-hemisphere cathodal (RALC), left-hemisphere anodal/right-hemisphere cathodal (LARC), and sham stimulation). The order of the three treatment was balanced across subjects. A direct current of 2.0 mA was introduced by two sponge electrodes taped on F3 and F4 in 10/20 EEG system. During tDCS the subjects made a series of two-alternative choices with immediate context trials (i.e. today and later) and delayed context trials (i.e. one month and later). One alternative, the immediate and smaller reward was fixed, while the other, the later and larger reward was varied according to an adaptive program. Essentially, the delayed reward would increase if the subjects dominantly chose the immediate option in the previous trials, and vice versa. Choices were modeled with a hyperbolic function, using maximum likelihood estimation. The discounting parameter was used as the impulsivity indicator in intertemporal choice.

Results: In the immediate context, the subjects exhibited smaller discounting parameter (i.e., less impulsive) under the LARC (but not the RARC) treatment as compared with the shame stimulation. However, such effect disappeared in the delayed context.

Conclusions: Previous brain stimulation studies on intertemporal choice have consistently shown maladaptive effects on decision-making. Here we demonstrated that the combination of excitation of left DLPFC and inhibition of right DLPFC can reduce intertemporal impulsivity. The fact that such effect was absent in the future context might reflect different roles of DLFPC in mediating intertemporal choices that involves immediate options versus those that both options are in the future.

Trollbridge: More options in moral judgments increases decision inertia

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Objective:
Trolley and Footbridge dilemmas (pull switch/push a man to sacrifice one to save five) are widely used to study moral judgments involving competing utilitarian and deontological values. How individual answer to these two types of dilemmas is used to infer moral preference as well as the underlying cognitive and emotional processing. Based on a large literature suggesting that preferences are constructed and very sensitive to contextual information/scope of the decision space, we examined the hypothesis that increasing the complexity of the moral decision would lead to decision inertia when making moral judgments.

Methods: Data was collected in Sweden (n=320) with a web-survey. The survey was divided into two parts. In part one participants answered two dilemmas in random order, Trolley or Footbridge followed by Trolley or Footbridge. In part two, participants answered two versions of a combination of the Trolley and Footbridge dilemma, that we call the Trollbridge dilemma. In the Trollbridge you can either pull the switch (kill one worker), push the man, or do nothing.

Results: Consistent with our prediction, when the choice gets more complex, more people restrain from making an active choice. In the Trolley dilemma 31.8% was inert, and in the Trollbridge 42.4% which is significantly higher, Chi-square, $p = .0060$. These peoples inertia cannot be explained simply by categorizing them as deontological overall, since they decides to act in the Trolley dilemma but are inert in the Trollbridge dilemma. Contradictory to previous studies we found no order effect when presenting the Trolley dilemma before the footbridge dilemma and vice versa.

Conclusions: We show that moral decisions are constructed on basis of the available information. When the moral dilemmas were combined significantly more participants opted not to act. These results suggest that widely used moral dilemmas such as the footbridge and trolley dilemmas should be used with caution when inferences about moral preferences are drawn. Our results suggest that decision makers may become both more utilitarian and more deontological depending on the decision information. Our behavioral finding should be complemented with studies of the brain correlates underlying emotional and cognitive processing of combined, complex, moral dilemmas.

THE INFLUENCE OF SEROTONIN DEFICIENCY ON CHOICE DEFERRAL AND THE COMPROMISE EFFECT

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Psychological and physiological states such as mood, hunger, stress and sleep deprivation are known to affect decision making processes and therefore crucially impact consumers' buying behavior. A possible biological mechanism underlying the observed variability is the context-sensitive variation in the levels of neuromodulators in the brain. In this study, we pharmaceutically manipulate the brain levels of serotonin, a neuromodulator that plays a role in regulating mood, reward, memory and attention in humans. Specifically, we study how serotonin levels influence (1) subjects' tendency to avoid buying, and (2) their preference for product options that are positioned as a compromise in a given choice set rather than for more extreme alternatives (i.e., the compromise effect). Using realistic choice scenarios in a binding decision framework, we find that serotonin depletion, that was previously shown to impair cognitive function, leads to a reduction in buying rates and eliminates the compromise effect. As such, this study provides neurobiological evidence for the assumption that the compromise effect is the result of deliberate and demanding thought processes rather than intuitive decision making.

Cognitive Control Predicts Use of Model-Based Reinforcement-Learning

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Objective: Accounts of decision-making have long posited the operation of separate, competing valuation systems in the control of choice behavior. Recent theoretical and experimental work suggest that this classic distinction between habitual and goal-directed choice may arise from two computational strategies for reinforcement learning (RL), called model-free and model-based RL, but the mechanism by which one system may dominate over the other in the control of behavior is a matter of ongoing investigation. To elucidate this question, we leverage the framework of cognitive control, examining how individual differences in utilization of goal-related contextual information—in the service of overcoming habitual, stimulus-driven responses—predict model-based behavior in sequential choice.

Methods: 83 participants first completed a version of the AX-CPT, a well-established cognitive task that assays participants' usage of contextual information in the service of overriding prepotent responses. Participants subsequently completed a two-stage RL task, for which Model-based and Model-free strategies make qualitatively different predictions about how rewards influence choice. We then examined, using mixed-effects logistic regression, whether the temporal signatures of cognitive control in the AX-CPT predict usage of model-based reinforcement learning in a sequential choice task

Results: The patterns of accuracy and reaction times in the AX-CPT task mirrored those of previous studies. Following previous work, participants' choice behavior exhibited signatures of both model-based and model-free strategies. As hypothesized, we found that usage of contextual information to bias behavior in a top-down manner (or "proactive" control) positively correlated with usage of model-based strategies in the RL task ($p < .05$). Dovetailing with this pattern of results, susceptibility to "bottom-up" or stimulus-evoked responding was negatively correlated with expression of model-based choice in the task ($p < .05$). Interestingly, the usage of context, the hallmark of cognitive control, actually yielded poor performance in certain circumstances in the AX-CPT, but was associated with more model-based behavior in the RL task.

Conclusions: Our experiments bring together two rather mature but historically separate literatures, revealing a novel correspondence between cognitive control and dual-systems decision-making, hinting that a common set of processes may underpin the two behavioral repertoires. Further, these data suggest an arbitration scheme whereby model-based behavior inhibits or overrides model-free choices.

Human Striatal Dopamine D2 Receptor Availability Associated with Probabilistic Reward Learning

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Objective: Prior research has implicated dopamine in reinforcement learning (RL) and decision making, but few studies have examined how individual differences in the human dopamine system may underlie differences in RL. Combining measures of the dopamine system obtained from PET imaging with behavioral measures of RL, we tested whether D2/D3 receptor availability is associated with the ability to learn from trial-by-trial feedback in a decision making task with probabilistic outcomes.

Methods: Twenty-five healthy adults completed an RL task and a PET scan of dopamine D2/D3 receptors (not concurrently; on different days). On each trial of the learning task, participants attempted to maximize earnings by choosing between two fractal cues (a stationary two-armed bandit). There were three sets of cue pairs. Each pair corresponded to a different condition: gain, loss, or neutral. In the gain condition, one cue was associated with a 66% chance of winning $1 (else $0), the other cue with a 33% chance of winning $1 (else $0). In the loss condition, one cue had a 66% chance of losing $1 (else $0), and the other had a 33% chance of losing $1 (else $0). Both cues in the neutral, control condition were associated with no change in earnings. The outcome of each trial was presented to the participant after each choice. Each cue pair's condition (i.e. gain, loss, neutral) and each cue's associated probability remained fixed throughout the experiment, allowing an observant participant to learn over time which cue within each pair had a higher expected value. Participants were instructed to attempt to maximize their winnings and they were paid in cash based on performance. On a separate visit, participants received a 5 mCi injection of [^{18}F]fallypride and underwent a PET scan to assess D2-like dopamine receptor availability.

Results: A whole-brain analysis revealed an association between striatal D2 receptors and RL; individuals with higher levels of receptor availability in the right ventromedial caudate and nucleus accumbens more frequently chose the higher expected value cue in both the gain and loss conditions. The effects were not specific to either gain or loss condition, but were instead relating to general probabilistic reward learning ability.

Conclusions: The findings suggest that the level of available D2/D3 receptors in the nucleus accumbens and caudate is associated with improved learning from probabilistic reward feedback. Consistent with prior animal work and pharmacological studies with humans, the results of our study using measures of dopamine receptors in the human brain provides direct evidence that the striatal dopamine system promotes reinforcement learning.

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Working Memory Training and Risky Decision-Making: An ERP Study in ADHD and Control Participants

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Objective: Patients with a diagnosis of attention deficit/hyperactive disorder (ADHD) are characterized by Working Memory (WM) impairment and by an abnormal sensitivity to reinforcement that is likely to influence cognitive processes such as decision making through unconscious ‘‘somatic marker signals’’ that arise from bioregulatory processes. During decision making it is important to determine whether the subjects are sensitive to the frequency but blind to the magnitude of a penalty/reward. In order to investigate whether a WM training can provoke a neural response having an influence on risky decision making, we designed a study where participants had to perform a probabilistic Investment Game (PIG), modified from the original Gneezy and Potters' neuroeconomic game (1997).

Method: 115 participants (22 yrs. old ± 0.28 SEM) were selected (N_{ADHD}=43, N_{CTRL}=72) for this study. The protocol included a pre-training session in the laboratory, 20 days of WM training at home, and a post-training session in the laboratory. In the laboratory the participants performed the PIG with an endowment of 20 points at the beginning of each trial, and requested to invest 0, 4, 8, 12, 16, or 20 points in a risky project with 1/3 chance to win. Outcomes were presented immediately after half of the trials (high frequency feedback, “HFFB”), while the other half were presented at the end of each block (low feedback frequency, “LFFB”). Conditions were alternated at each block. The whole session was composed of 10 games x 4 blocks x 4 trials, overall 160 trials. All participants played the adaptive version of the Dual N-Back, which consisted of 20 blocks of 20+N trials, composed of visual and auditory stimuli. During the sessions, EEG was continuously recorded using 64 active Ag/AgCl electrodes and referenced to the link earlobes. During the WM training, half of the participants played the adaptive variant of the Dual N-Back (training group), whereas the other half played the Dual 1-Back for the whole training period (base group).

Results: We did not observe a significant change in the total gains ($F_{(1,94)}$=0.842, p=0.361) and risky behavior ($F_{(1,94)}$=0.192, p=0.662) provoked by WM training, but changes in the activity of brain networks were assessed by ERPs. A N200-P300 complex was triggered by the self-paced start of trial. The amplitude of P300 was larger in all trained individuals in both LFFB and HFFB conditions. Following the activity triggered by the selection of the invested amount, we observed that the amplitude of a P250 component was larger in all trained participants in the LFFB condition (p<1%). This effect was reduced in the HFFB condition and observed on parieto-central sites, Cz, CPz, Pz and POz in control individuals, (p<5%).

Conclusion: The results of this study suggest that the working memory training affected the brain activity during the first 500ms associated with risk taking decision processes. In ADHD participants, the frontal sites appeared the most affected, whereas global brain activity was likely to be affected in controls.

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Dopamine-Related Genetic Influences on Intertemporal Choice

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Objective: When choosing between an immediate and a delayed reward, people tend to 'discount' the values according to their expected delays. The aim of the study was to explore dopamine-related genetic influences on the discounting of future reward options. We focused on single nucleotide polymorphisms (SNPs) associated with striatal and frontal dopamine function. In particular, we investigated the role of the Val158Met polymorphism of the cathenol-O-methyltransferase (COMT val158met) polymorphism.

Methods: For study 1, 89 healthy participants performed an intertemporal choice task which asked participants to choose between an earlier reward and a delayed reward. For study 2, Functional Magnetic Brain Imaging (fMRI) activity was collected from 70 healthy individuals using a 3T GE MR scanner while performing an intertemporal choice task. Genomic DNA was extracted from saliva samples and analyzed for SNPs associated with striatal dopamine function (DAT1/SLC6A3, DRD2 C957T, DRD4) and frontal dopamine function (COMT Val158Met). Two well-known discount utility models were used to characterize participants' discount tendencies and repeated measures ANOVAs were used to compare discount parameters across genotypes.

Results: Study 1 revealed genotype-related differences in intertemporal choice behavior, with Val homozygotes exhibiting a behavioral tendency to more frequently choose the delayed option ($p<.01$). In accordance with this finding, modeling of the behavioral data showed smaller discount parameters for Val- homozygotes when compared to Met- carriers ($p=.014$). Study 2 revealed enhanced frontal activation associated with delayed choices, whereas enhanced striatal activation was associated with earlier choices.

Conclusions**:** We provide evidence of dopamine-related genetic influences on intertemporal decision-making. Our results point to the role of the COMT Val158Met in supporting the frontal dopaminergic mechanisms associated with delayed choice, as opposed to the more impulsive immediate choice associated with striatal dopamine activity.

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Using the Drift-Diffusion Model to Improve Preference Measurement and Choice Prediction

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Objective
An important goal for neuroeconomic research is to generate models that translate into applications for economics. One fundamental problem is using choice data from one domain to make out-of-sample predictions for a related choice environment. A second agenda of importance to neuroeconomics is how different reward attributes are integrated to construct preferences. To address these challenges, we employ an algorithmic model of choice, the drift-diffusion model (DDM). To demonstrate the robustness and generalizability of our approach, our tests are completed on three distinct and independent datasets.

Methods
We first investigate if it is possible to improve out-of-sample predictions of choice in comparison to a canonical approach, the logistic choice model. To perform this test, we construct experiments that involve two independent choice tasks. The two simple choice tasks involved appetitive snack foods. The test data in Experiment 1 (N=31) were choices between pairs of item, and the test data in Experiment 2 involved bundles (four) of foods (N=34). To investigate how different reward attributes are integrated when constructing preference for available items, Experiment 3 presented subjects (N=25) with mixed-prospect gambles.

Results
We find that the DDM consistently outperforms the logistic prediction model in both E1 and E2. This improved predictive power (i.e., the ability to correctly predict an out-of-sample choice) is particularly stark for intermediate choice probabilities (e.g., 25% or 75%). In E3, we also show how the DDM parameters can be employed to predict attribute weighting of simple gambles consistent with loss aversion. The results of E3 reveal that the key parameter in the DDM, the drift rate, reflects attribute weighting of simple gambles consistent with risk aversion and loss aversion. Further, in all three experiments, the fitted parameters from the DDM can provide additional predictions along another dimension of the choice, decision time, due to the ability of the DDM to generate response time predictions.

Conclusions
All of these results showcase the value of incorporating 'process' data, such as response times, into the estimation of parameters in economic models used to measure preferences or make choice predictions.

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