



# ASSOCIATION FOR CONSUMER RESEARCH

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## **Brain Processes Underlying the Influence of Prior Gains and Losses on Decisions Under Risk**

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The risk attitudes of consumers generally depend on previous outcomes. Here we study behavioral changes and differential brain activations related to prior relative gains and losses. Subjects showed decreased risk aversion after both relative gains and losses. Neuroimaging results revealed that relative gains and losses are processed similarly to actual gains and losses, indicated by ventral striatum and medial prefrontal cortex activity. During subsequent choices, however, insular cortex and right inferior frontal gyrus showed differential activation depending on the prior experience. Activity in these neural regions, related to emotion and control, also correlated with the magnitude of observed behavioral changes.

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## SPECIAL SESSION SUMMARY

### Multiple Systems for Choice and Valuation: New Perspectives from Decision Neuroscience

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#### SESSION OVERVIEW

Typical consumer decisions involve the consideration and integration of a diverse range of information about the appeal of available options, decision context and situational history, and the importance and implications of making the 'right' choice. While behavioral studies have illuminated much about the nature of consumer decision making, teasing apart differences in how contributing underlying processes operate is a difficult problem for these approaches alone. Neuroscientific investigations of decision making offer direct and real-time access to these component processes, and so can crucially augment and enrich our current understanding of consumer decision making.

The objective of this session is to present an interlocking set of such insights into the multi-dimensional bases of decisions. The common thread is exploring precisely how different aspects of decision making marshal common versus dissociable underlying processing systems, and the predictive and explanatory implications thereof for central issues in consumer psychology and behavioral decision research. Bolstered by pertinent behavioral results, we employ functional magnetic resonance imaging (fMRI) to develop a more complete picture of the nature of decisions in scenarios akin to many typically faced by consumers. These findings in turn may inspire and shape further neural and behavioral investigations into how dissociable underlying choice and valuation systems may be divergently affected under specific conditions.

Hytönen, Baltussen, van den Assem, Klucharev, Smidts and Post present strong evidence for distinct neural networks active during and after experiencing gains and losses, and for how these distinguishable circuits drive path dependence in risky decision behaviors. From such prior-history effects on choices we move to future-reward discounting, where Figner, Johnson, Krosch, Steffener, Chu and Weber reveal distinguishable neural systems underlying asymmetric expressions of relative impatience across differently framed decisions regarding immediate versus future rewards. Neural circuits for affect, valuation, and action-impulse that these papers identify obtain converging support from the findings of Litt, Plassmann, Shiv and Rangel dissociating computations of motivational salience from valuation at the time of decision making. The striking divergences they observe support growing interest by behavioral decision researchers in teasing apart these components of value, and are consistent with our overarching theme of illuminating the importance of disentangling multiple distinct systems underlying valuation and decision making.

The papers in this special session feature data collected using both behavioral and neuroimaging measures. Our discussion leader, Carolyn Yoon, has conducted important behavioral studies of valuation, memory, and decision making, and is at the forefront of decision neuroscience research in consumer contexts and broader domains. While our techniques will appeal directly to those interested in (or who appreciate the growing importance of) neuroscientific and physiologically informed consumer research, our results are of broader significance to an audience interested in the nature of consumer decision making. Taken together, the findings described in this special session help to pry open the 'black-box' of the act of deciding, by revealing precise mechanisms for how dissociated and shared contributing sub-systems are engaged, interact, and lead to specific patterns of overt behavior.

#### EXTENDED ABSTRACTS

##### **"Brain Processes Underlying the Influence of Prior Gains and Losses on Decisions under Risk"**

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A large body of behavioral experiments has convincingly shown that the risk attitudes of consumer decision makers for a given risky choice problem generally depend on the outcomes of previous choice problems (i.e., path dependence). Most notably, Thaler and Johnson (1990) showed that the average decision-maker tends to take more risk if she has a chance to gain back a previously experienced loss, the "break even effect". Moreover, after experiencing a gain which cannot be lost, she also has a greater risk appetite, the "house money effect". These effects are pervasive outside the laboratory (Post et al., 2008), and they are expected to be common in, for example, sequential choice behavior by private investors.

In this fMRI experiment we study the behavioral changes and brain activations related to prior experiences in decision making under risk. First, we test whether removal of options from a set of possible outcomes is interpreted as a positive or negative event in the brain, relative to the overall composition of an outcome set. Second, we explore how affective neural reactions to gains and losses influence and drive future choices.

**Task.** Subjects (N=22) undergoing fMRI made decisions between risky lotteries and sure amounts of money (offers). Each choice problem consisted of either one or two sequential stages, depending on a subject's behavior. In the first stage, subjects selected between a lottery with three outcome options and an offer. If a subject chose the offer, they proceeded to the next choice problem. If a subject took the risk of choosing the three-outcome lottery, one outcome option was randomly removed from the lottery (outcome phase). The subject then proceeded to the second stage of the choice problem, where they chose between a lottery with the remaining two outcome options and an updated offer. The choice problems were designed so that subjects faced a fixed set of 24 lotteries and offers following a previously experienced relative gain (smallest outcome option removed), neutral outcome (middle outcome option removed), and a relative loss (highest outcome option removed). The 24 lotteries were thus replicated three times, with the same second-stage lottery evaluated after a loss, gain and neutral outcome. This within-subjects design enabled us to isolate the effects of previous relative gains and losses on future choices between lotteries and offers.

**Analysis.** To test the nature of subjects' risk-seeking attitudes after relative gains and losses, we compared the percentage of lottery choices for identical sets of second-stage choices across the three conditions, i.e., following a previous relative gain, neutral, or relative loss outcome. In the analysis of the brain data we concen-

trated on two time windows: the outcome phase, where one outcome option was removed from the lottery, and when making the second-stage choice. For both time windows we located brain areas that were sensitive to relative gains and losses in the choice problem. Using regression analyses we examined which neural regions activated during the second-stage correlated with changes in the percentages of lottery choices between the conditions.

**Behavioral Results.** Participants showed decreased risk aversion (i.e., an increased percentage of lottery choices), relative to following a prior neutral outcome, following both a prior relative gain ( $p < 0.05$ ) and a prior relative loss outcome ( $p = 0.06$ ). These results indicate that prior experiences influence future choices under risk in accordance with the house money and break even effects, even in a within-participants design.

**Neural Results.** In the outcome phase, where one of the three lottery prizes was randomly removed, we found activity in the ventral striatum and medial prefrontal cortex. These areas were most active when participants experienced a relative gain and least active when a relative loss occurred. These brain areas have been previously related to the processing of unexpected rewards (O'Doherty, 2004; Delgado, 2007). Furthermore, these regions deactivate for losses even more strongly than they activate for gains, reflecting loss aversion (Tom et al., 2007). The present findings thus indicate that the brain does indeed process lottery prize removals as relative gains and losses, even before the actual lottery win or loss is revealed. This is an important extension of existing results on reference dependence of lottery outcomes (Breiter et al., 2001).

The effects of previous outcomes during the second-stage choice were reflected by activity in the operculo-insular cortex and anterior cingulate cortex, regions known to be related to cognitive control, emotions, and pain processing (Carter et al., 1999; Frot & Mauguière, 2003). Activity was higher in these regions in the loss condition than in the gain condition. In an additional regression analysis, we found that the insular cortex activity correlated with decreased risk aversion in the loss condition as compared to the neutral condition ( $b = 0.5$ ,  $p < 0.05$ ), which is consistent with prior findings linking insular activity to choosing high-risk options (Platt & Huettel, 2008). Another region showing increased activity after loss outcomes during the second-stage choice was the right inferior frontal gyrus, which has previously been related to suppression of responses, and linking emotional reactions and motor actions (Garavan et al., 2006; Schulz, 2009). Here we found that the smaller the difference in right inferior frontal gyrus activity between the gain and neutral conditions, the more lottery choices increased relatively after a gain ( $b = -0.43$ ,  $p < 0.05$ ). These results suggest that prior events can lead to an increase in affect-related neural activity and a decrease in control in subjects vulnerable to biases.

In sum, these results demonstrate that removal of an option from a set of possible outcomes is processed in the brain as a positive or negative event relatively to the original outcome set, and that activity involved in processing emotions and control distinguishably drives path dependence in risky decision behaviors.

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## "Impatient No More! Impulsivity in Choice Depends on How you Frame the Question"

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One of the most important consumer decisions is whether to consume now, or wait until later. This willingness to trade immediate rewards for later benefits determines how much we save for retirement and whether we have that extra drink at a party (Mischel et al., 1969; Weber et al., 2007). While classical economics assumes exponential (constant per-period) discounting, people in fact discount future outcomes more steeply when they have the opportunity for immediate gratification than when all outcomes occur in the future, that is, they exhibit hyperbolic discounting (Frederick et al., 2002).

Many different explanations exist for hyperbolic discounting. A prominent example is the beta-delta model (Laibson, 1997), in which total discounting is the (quasi-hyperbolic) sum of two exponential discounting components, one (delta) that is present in all intertemporal choices, the other (beta) that is present only when immediate rewards are one of the choice options. Imaging evidence for this form of discounting decomposition was provided by McClure and colleagues (2004).

However, this approach and many other analyses ignore a robust empirical fact: people are much more impatient when delaying consumption (e.g., demanded price reduction for a downgrade from express to regular shipping) than when given the opportunity to accelerate consumption (e.g., willingness-to-pay for

an upgrade from regular to express shipping; see Loewenstein, 1988). Loss aversion, as formalized by prospect theory (Kahneman & Tversky, 1979), has been used to explain such asymmetric discounting. People are assumed to encode delay of consumption as a loss and acceleration as a gain, and delays are thereby proposed to be more painful than accelerations are pleasurable. This account is silent, however, regarding the precise psychological mechanisms giving rise to any such loss aversion and consequent asymmetric discounting. Moreover, it predicts a non-existent relation between an individual's degree of loss aversion and the degree of impatience asymmetry.

An alternative, more process-specific class of explanations suggests that different kinds of valuations (acceleration vs. delay; buying vs. selling prices) shift the decision-maker's focus of attention, consistent with differences in implicit goals (Fischer et al., 1999; Weber & Kirsner, 1997). Query Theory (Johnson et al., 2007) hypothesizes that decision defaults influence the sequence of retrieval of evidence, with the expected option (immediate consumption in delay decisions, larger but later consumption in acceleration decisions) being considered first, and with initial queries generating output interference that reduces the output of subsequent queries.

**Task.** To explore these questions regarding the basic processes underlying asymmetric discounting and impatience, we ran an online investigation of choices made by 20 participants undergoing fMRI. Participants made binary choices between gift certificates, using stimuli based on those used by McClure et al. (2004). In each of approximately 120 trials, participants made a delay or accelerate decision between a smaller/sooner (SS) and a larger/later (LL) reward. Amounts (ranging from \$15 to \$85), times of delivery (either immediately, i.e., day-of-participation, 4 weeks later, or 6 weeks later), and relative time difference between SS and LL (either 2 or 4 weeks) varied across trials. After finishing the scanning portion of the experiment, one of the participant's choices was randomly selected and paid out for real, and at the designated time of delivery for that prize on that trial, participants received the gift certificate they had chosen in the selected trial. This design enabled us to investigate neural activation differences underlying observed impatience asymmetries between delay decisions and accelerate decisions, further contrasting (a) choices between an immediate and a future reward; with (b) choices between two future rewards. This allowed investigation of relative differences in hyperbolic discounting between delay and accelerate decisions.

**Behavioral Results.** We observed significant effects (all  $p$ 's < .001) of the length-of-delay-time difference (with participants being more patient for shorter wait periods), the magnitude of the earlier reward, and the relative difference between SS and LL (indicating a trade-off between the cost of waiting and the increased reward of the LL). Moreover, and as predicted a priori based on Query Theory, we found hyperbolic discounting only in the delay condition, and not in the accelerate condition, with more impatient choices if a reward was immediately available as opposed to when both rewards were only available in the future.

**Neural Results.** The fMRI data revealed important differences in the two ways of measuring preference that were consistent with Query Theory. Contrasts comparing delay and accelerate decisions confirmed three hypotheses. First, as consistent with the Direction Hypothesis, greater activation in delay decisions was observed in key valuation-related brain regions: ventral striatum, medial prefrontal cortex, and orbitofrontal cortex. This suggested the distinguishable involvement of valuation circuits for each direction, delay or accelerate. Since Query Theory suggests that these judg-

ments are constructed from recollection, our observation (particularly with immediate rewards) of activation of bilateral hippocampus and an additional network involved in prospective judgment confirmed the Memory Hypothesis. Finally, we predicted and indeed observed increased activation of anterior cingulate cortex in delay decisions, a region crucial to the monitoring of response conflict and online performance (e.g., Carter et al., 1998; Botvinick, Cohen, & Carter, 2004), and so consistent with our Conflict Hypothesis.

In ongoing additional analyses, we are relating individual differences observed in this study to (1) results of Diffusion Tensor Imaging (DTI) measurement of white matter neural-tract connectivity between key regions of interest, (2) observed activations in target regions, and (3) eye movement recordings done during imaging. These approaches provide further evidence for specific relationships between our results and similar phenomena and neural activation patterns studied in extant research on memory, choice, and valuation.

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### “Distinguishable Neural Circuits for Motivation and Valuation Underlying Decision Making”

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Many common consumer decisions involve considerations of value, to determine the type or nature of appropriate response; and motivational salience, influencing strength of engagement in both decision context and response implementation. Mounting research indicates important ways in which valuation and motivational components of decisions are dissociable in terms of underlying psychological processes and behavioral outcomes (e.g., Higgins, 2006). While conceptualizations of this disjunction vary—from “hedonic states” versus “hedonic stakes” (Lyubomirsky & Ross, 1999) to wanting versus liking (Winkielman & Berridge, 2003)—the notion that valuation and motivation may act in different ways and through distinct means seems of express importance to understanding the bases of consumer decision making.

Neuroscientific investigations of motivation and valuation have proven very effective in establishing the extent and limits of disjunctions between these psychological constructs, by revealing how their respective biological substrates differ, overlap, and interact (Berridge, 1996; Zink et al., 2004). This in turn sheds light on the basic psychological mechanisms influencing observed patterns of overt behavior. We conducted an fMRI study that explores dissociations in humans between specific valuation and motivational processes active and involved at the time of decision making, using an explicit and clear conceptualization of such a disjunction.

**Task.** During scanning, subjects ( $N=20$ ) made a series of 240 choices involving different appetitive and aversive foods (60 distinct items, randomized and repeated once per session, for two sessions). Subjects were instructed, for each trial, to indicate (within a 2s interval) their willingness to eat the displayed food-item at the end of the experiment, using one of four response keys: “Strong No”, “No”, “Yes”, or “Strong Yes”. Subjects were told that at the end of the experiment, a random trial would be selected: they would actually receive that trial’s food item to eat if they responded “Yes” or “Strong Yes” on the trial, but would not if they responded “No” or “Strong No”. It was reiterated to subjects that “the response you gave on that [randomly chosen] trial will determine whether or not you will be asked to eat that food item at the end of the experiment.” Thus, subjects faced response decisions involving valuations of food items under motivation to respond accurately in line with those valuations. Subjects were asked not to eat immediately prior to the experiment, and were pre-screened for at least occasionally eating the food stimuli generally classifiable as appealing (snack foods, chocolate, etc.).

**Analysis.** Valuation was captured by observing the specific response given on any trial, and taken to be increasing from “Strong No” to “No” to “Yes” to “Strong Yes”. In contrast, we conceptualized motivation as the cross-valence strength of the response given on a trial: i.e., “Strong” responses were considered to be of greater motivational engagement than non-“Strong” responses. We thus coded the four possible trial responses as RESP {“Strong No”=-2, “No”=-1, “Yes”=+1, “Strong Yes”=+2}, and included RESP (valuation) and IRESP (motivation) as modulators of food item presentation in the AR(1) GLM estimated to analyze trial events in the experiment. Single-subject and group-level contrasts were calculated to determine brain regions in which activation during decision trials was 1) modulated by valuation, but not motivation; 2) modulated by motivation, but not valuation; and 3) modulated by both motivation and valuation.

**Behavioral Results.** In line with our conceptualization of motivation as response strength, subjects responded significantly faster for Strong Yes/No than non-strong Yes/No ( $t(77)=4.22$ ,  $p<.00005$ , computed across subjects using means pooled within-subject). Additionally, subjects’ responses were correlated to a pre-scanning task in which they rated their overall liking of each food item used in the experiment, in order to test whether scanning-trial responses accurately matched valuations in both valence and intensity/strength. This correlation yielded  $R^2=.9514$ , supporting this contention.

**Neural Results.** Increased activity modulated by valuation was observed bilaterally in medial orbitofrontal and rostral anterior cingulate cortices, consistent with a wide range of findings in the cognitive neuroscience of decision making (e.g., Plassmann, O’Doherty, Shiv, & Rangel, 2008). Activity observed in dorsal posterior cingulate is consistent with work on reward-related signals in monkeys (McCoy et al., 2003). Additional valuation-modulated activity in precuneus and parahippocampal gyrus may be related to memory retrieval-related functionality previously observed for each of these regions: foods valued more highly by subjects are likely to be more familiar than the foods chosen to be generally unappealing (e.g., squash baby food, clam juice).

Increased activity modulated by motivational salience was observed bilaterally in posterior insula, dorsal anterior cingulate, supplementary motor areas, and primary motor cortex. This network of brain regions suggests several important conclusions regarding how motivational salience is represented in the brain and directs overt behavior. Insula activity correlated with cross-valence motivational salience is in contrast to a preponderance of work showing insula encoding primarily negative responses, such as disgust. These previous findings might be re-interpreted as indicative of the relatively greater motivational salience of those strong negative feelings, in a manner analogous to what has been argued for the amygdala (Anderson et al., 2003). In line with findings showing addiction and craving disruption with insula damage (Naqvi, Rudrauf, Damasio, & Bechara, 2007), our findings suggest that increased (cross-valence) motivation engages the insula, and that this representation of a high motivational state activates the planning and selection of an appropriate response action in dorsal anterior cingulate and downstream motor regions (similar to an account of ADHD by Bush et al., 1999).

Finally, different sub-regions of the nucleus accumbens (NAcc) were either distinctly or overlappingly modulated by valuation and motivation. This suggests a potential resolution to an ongoing debate over whether activity in NAcc is involved in encoding actual levels of reward or valuation, or rather representations related to the incentive salience or behavioral relevance of stimuli (Rodriguez, Aron, & Poldrack, 2006; Cooper & Knutson, 2009). Our results suggest that these divergent functionalities may be implemented in distinct but partially overlapping sub-regions of NAcc. Thus, consumer decision making seems grounded in dissociable but not disjoint sub-systems computing choice value and motivational salience.

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