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Running head: CONTEXT EFFECTS ON CHOICE

Money or Life:

Behavioral and Neural Context Effects on Choice under Uncertainty

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## Abstract

Despite robust evidence from behavioral decision making demonstrating context effects on choice, most neural studies on choice under risk and uncertainty have involved monetary gambles. We instructed participants to make choices under uncertainty in life and cash domains. Participants exhibited greater risk aversion, conflict, and sensitivity to negative feedback in the life domain, which we attribute to valuation of human lives. Supporting this assertion, choices to save lives activated the dorsal striatum, consistent with its role in context-sensitive reward processing. In contrast, choices to save cash activated the posterior insula, which we attribute to its role in probability signaling and risk prediction. Our findings highlight dissociable and context-dependent neural systems underlying choice under uncertainty.

*Keywords:* Context effects, decision making, risk, uncertainty.

Neural studies of choice under conditions of risk or uncertainty have relied heavily on monetary gambling tasks. This reliance has been motivated by early domain-independent views of decision making (e.g., Bernoulli, 1738/1954; Savage, 1954; von Neumann & Morgenstern, 1947), largely setting the course for later empirical studies (e.g., Kahneman & Tversky, 1979). According to these early ideas, all decisions could essentially be represented by a gambling metaphor with only two pertinent variables—degrees of value and degrees of belief—whose product expressed the (subjective) expected utility (or worth) of the gamble. The currency of the gamble (e.g., money earned, lives saved, territory acquired, etc.) was believed to be of no particular consequence in terms of how decisions are made.

However, ample behavioral evidence of context effects on decision making indicates that monetary gambles may not be representative of decisions in other domains (Goldstein & Weber, 1997; Rettinger & Hastie, 2001; Wagenaar, Keren, & Lichtenstein, 1988). In fact, not only have content effects been shown to affect decision outcomes, but they also exert predictable effects on the selection of decision strategies. This led Goldstein and Weber (1997) to conclude that the field of judgment and decision making has reached a stage in which context-dependence must be seen as central to theory, as something that cannot be ignored without incurring a severe loss of explanatory completeness.

In the present research, we manipulated context by contrasting choices made in the domains of life and cash (see Kühberger, 1998; Schneider, 1992). Although formally identical decisions involving lives and cash can be contrasted along multiple dimensions, one dimension which has received considerable theoretical attention involves the

elicitation of morally relevant considerations (Rettinger & Hastie, 2003). Specifically, given the moral value attached to lives, participants may be less willing to engage in tradeoffs that involve loss of lives compared to cash (e.g., Baron & Spranca, 1997). This suggests that decisions involving human lives may make decision makers more sensitive to the moral prospect of failing to save those lives (Mandel & Vartanian, 2008; Tetlock, Kristel, Elson, & Lerner, 2000), with the consequence of motivating a change in emphasis of relevant decision variables *vis-à-vis* other content domains.

We propose that the decision context involving human lives will influence choice and the selection of decision strategies. Furthermore, extending the behavioral literature on decision making, we propose that activations in dissociable neural systems that accompany specific content manipulations can shed light on the psychological processes underlying the observed context effects. Behaviorally, we predicted that compared to choices involving cash, choices involving life would prompt greater risk aversion, conflict, and sensitivity to negative feedback. We measured risk aversion by the proportion of choices made that favor the riskier of two options, conflict by the response latency to make choices, and loss sensitivity by the likelihood of changing choice options as a function of negative feedback.

Neurologically, it is known that making value-based decisions activates a distributed network in the brain (Frank, Cohen, & Sanfey, 2009; Sanfey, 2007). This network encompasses multiple systems, each of which serves specific computational demands involved in making choices; including representation, valuation, action selection, outcome evaluation, and learning (Rangel, Camerer, & Montague, 2008). Furthermore, the cortical systems activated in making financial and moral decisions

overlap considerably with this network, as well as with each other. This is perhaps not surprising, given that choices in these two domains are characterized by a subset of shared computations.

Despite the overlap, there is evidence to suggest that decisions involving lives and cash also involve some dissociable cortical networks. The basis for our prediction of a neural dissociation is derived from two lines of behavioral evidence. First, work in moral psychology suggests that lives have a higher intrinsic value compared to cash. This valuation of life should therefore result in higher activation in structures that underlie the computation of reward when participants make choices in the life than cash domain, primarily the orbitofrontal cortex (OFC) and the striatum (see Montague, King-Casas, & Cohen, 2006; O'Doherty, 2004). The involvement of these two structures in the computation of value is so prevalent that it has been suggested that a system involving the orbitofrontal and striatal neurons may underlie valuation of rewards irrespective of the modality of the rewarding stimuli (Montague & Berns, 2002). Furthermore, the OFC and the striatum are particularly responsive to rewards that change, accumulate, or are learned over time (Montague et al., 2006)—features that characterize the paradigm employed in the current experiment.

Second, behavioral studies suggest that the prospect of saving lives may motivate decision makers more than the prospect of earning cash (Rettinger & Hastie, 2003). Within the striatum, this motivational drive points to the engagement of the *dorsal* striatum in particular, given its sensitivity to motivational context (Delgado, Locke, Stenger, & Fiez, 2003; Delgado, Stenger, & Fiez, 2004), as well as goal-directed action to

increase reward in instrumental learning paradigms (O'Doherty, 2004; O'Doherty et al., 2004; see also Wrase et al., 2007).

In contrast, we hypothesized that making choices in the cash domain would be primarily geared toward maximization of earnings, and would therefore involve structures known to underlie risk prediction and probability signaling. In particular, we focused on the anterior cingulate cortex (ACC) and the insula. Although the role of the ACC in risk prediction, probability signaling, and error likelihood prediction is well established (see Brown & Braver, 2005, 2007), recent neuropsychological and neuroimaging evidence also points to the role of the insula in both processes. For example, patients with insular lesions are impaired in risky decision making, especially in risk prediction and probability signaling (Clark et al., 2008; Weller, Levin, Shiv, & Bechara, 2009). Furthermore, neuroimaging studies have implicated the anterior *and* posterior insula in risk prediction and probability signaling (Carlsson et al., 2006; d'Acremont, Lu, Li, Van der Linden, & Bechara, 2009; Montague & Lohrenz, 2007; Preuschoff, Quartz, & Bossaerts, 2008). The involvement of the insula in risk prediction and probability signaling may be due to its role in the mental representation of the homeostatic states associated with the experience of risk (Xue, Lu, Levin, & Bechara, 2010), consistent with its more general and well-established role in interoception (Craig, 2002).

Given the neurological evidence, we hypothesized that the (dorsal) striatum and the OFC would be engaged more in life problems, whereas the ACC and insula would be engaged more in cash problems. We tested this hypothesis using data from functional magnetic resonance imaging (fMRI).

## Method

### *Participants*

Participants were sixteen neurologically healthy volunteers (five males, eleven females) with an average age of thirty-one years ( $SD = 11$ ), recruited from the Greater Toronto Area.

### *Materials and procedure*

The Gambling Task (fMRI Version 3.0.1) (NTT Systems Inc.) was used for data collection. Participants were instructed to complete a series of gambles between two options, presented in the form of two decks. They received feedback following each choice (see Figure 1). One option was paired with a certain outcome and the other with a variable, uncertain outcome. The expected values of the two decks were identical, and unknown to the participants. Half of the trials involved choices to save lives, whereas the other half involved choices to save cash. In life problems, the certain deck resulted in saving 8 villagers (out of 24), whereas the outcome linked to the uncertain deck varied between saving 0 villagers ( $p = .67$ ) or 24 villagers ( $p = .33$ ) (out of 24). In cash problems, choices from the certain deck resulted in saving \$800 (out of \$2,400), whereas the outcome linked to the uncertain deck varied between saving \$0 ( $p = .67$ ) or \$2,400 ( $p = .33$ ) (out of \$2,400).

In the scanner, data were collected in two consecutive runs. One run was for cash trials and the other for life trials, the order of which was counterbalanced across participants. Each run consisted of two blocks of 24 trials of identical structure. Each trial began with a 2s presentation of a fixation point, which was followed by a 6s window during which a motor response could be collected (i.e., choice phase). Upon recording a

response the program revealed the outcome associated with the selected deck for the remainder of the 6s window. Following the termination of the 6s response window the outcome associated with the unselected deck was also revealed for 2s (i.e., feedback phase). Thus, the combined duration of the choice and feedback window was 8s, regardless of the participants' response latency (see Figure 1). The complete duration of a trial was 10s.

Prior to the initiation of each block, a slide presented for 4s indicated the relevant domain (i.e., "LIFE" or "CASH"). Following the termination of each block, a slide presented for 2s indicated the total savings from that block. The order of sessions and trials within each block was randomized for each participant. Response hand was counterbalanced across participants. The duration of each run was 8.2 min (i.e., 16.4 min of scans for the entire experiment).

In advance of entering the scanner participants completed ten practice trials for familiarization with the timing of the trials and usage of the keypad. The participants were instructed to read the following cover story prior to completing the pilot run:

This experiment involves asking you to make decisions in some hypothetical situations with lives and cash at stake. There will be a cover story to describe the situation, followed by two possible courses of action on each problem. The options available to you in relation to each problem are binary. Your task is to decide which alternative you prefer to take. After selecting one of the options, you will also be presented with the alternative that you did not choose. You will be given a few seconds to read the problem, a few seconds to make a choice, and a few seconds to view the alternative you did not choose. You should make an effort to respond on each problem, but should that not happen, you will see a "Timeout!" message after which the program will simply move to the next problem. Once you have made a response you will not be able to go back and change the answer you gave in the earlier problems.

You should treat each one of the problem scenarios as an independent problem, which means that you should judge each problem without being affected by the decisions you have already made for previous problems. When examining a

problem, your estimates of the likelihood of some event should be strictly based on the probabilities given in each problem, and not on your personal intuition or experience about the likelihood of a certain event occurring. Also, when you make these decisions, assume you are not personally involved in the situations, and that for your chosen course of action you will remain anonymous. With this in mind, please make your preferred choices. Finally, before you make a choice, be sure you have read over the cover description of the situation very carefully.

The participants then proceeded to complete the pilot trials. Before entering the scanner, the experimenter confirmed that the participants understood the task requirements. Given the hypothetical nature of the task, participants were not told that cash decisions would be honored, and they were not.

#### *fMRI acquisition and analysis*

A 3 Tesla magnet (Signa 3T/94 with EXCITE HD 12.0, GE Healthcare, Waukesha, WI) was used to acquire T1 anatomical volume images (.086 × .086 × 1.4mm voxels). For functional imaging, T2\*-weighted gradient echo spiral-in/out acquisitions were used to produce 26 continuous 5mm thick slices (repetition time [TR] = 2000ms; echo time [TE] = 30ms; flip angle [FA] = 70°; field of view [FOV] = 200mm; 64 × 64 matrix; voxel dimensions = 3.1 × 3.1 × 5mm), positioned to cover the whole brain. The first five volumes were discarded to allow for T1 equilibration effects, leaving 246 volumes per session.

Data were analyzed using Statistical Parametric Mapping (SPM5). Head movement was less than two mm in all cases. All functional volumes were spatially realigned to the first volume. Given that the volumes were acquired using a descending sequence with short TR, slice timing to correct for variation in acquisition time followed realignment (Huettel, Song, & McCarthy, 2004). A mean image created from realigned volumes was spatially normalized to the MNI EPI brain template using nonlinear basis

functions. The derived spatial transformation was applied to the realigned T2\* volumes, and spatially smoothed with an eight mm FWHM isotropic Gaussian kernel. Time series across each voxel were high-pass filtered with a cut-off of 128s, using cosine functions to remove section-specific low frequency drifts in the BOLD signal. Condition effects at each voxel were estimated according to the GLM and regionally specific effects compared using linear contrasts. The BOLD signal was modeled as a box-car, convolved with a canonical hemodynamic response function. Each contrast produced a statistical parametric map consisting of voxels where the  $z$ -statistic was significant at  $p < .001$  (uncorrected for multiple comparisons).

Each Region of interest (ROI) was localized based on published reports (and where relevant, the coordinates were converted from Talairach to MNI coordinates). For the life–cash contrast, our ROIs included the OFC and the striatum. Within the OFC, we focused on the medial (–1, 27, –18) and central (–27, 36, –6 and 24, 36, –3) regions, given the involvement of both regions in the computation of value in the context of financial decision making (Hare, O’Doherty, Camerer, Schultz, & Rangel, 2008; see also Kringelbach & Rolls, 2004). We also focused on the dorsal striatum (–8, 22, 0, O’Doherty et al., 2004), given its role in goal-directed action to increase reward (see also Balleine, Delgado, & Hikosaka, 2007). For the cash–life contrast, we focused on the ACC and the insula. Specifically, Brown and Braver (2007) have shown that the ACC (9, 26, 33) is sensitive to risk prediction (see also Barch et al., 2001), whereas Preuschoff et al. (2008) have shown that the anterior (32, 16, –3 and –31, 15, –2) and posterior (50, –12, 6) insula are sensitive to risk prediction errors. The ROIs were spheres (10-mm radius) centered on voxels that showed peak activation in the aforementioned studies,

using small volume correction (SVM) in SPM5. Furthermore, because we did not have lateralized hypotheses, we explored activations within each ROI in both hemispheres. Reported activations survived voxel-level intensity threshold of  $p < .05$  using a random-effects model, corrected for multiple comparisons (Bonferroni family-wise error) within respective ROIs.

## Results

*Behavioral.* Skewness and kurtosis analyses demonstrated that the distribution of choice data (i.e., percentage selection from the risky deck) did not deviate from normality (both  $ps > .05$ ). Consistent with previous studies involving decisions with outcome feedback (Barron & Erev, 2003), overall, participants were risk averse. Specifically, they chose the riskier option on 41% of trials, a rate significantly lower than chance,  $t(15) = -2.92, p < .05$ . As predicted, participants were more risk averse in the life than cash domain,  $t(15) = 2.72, p < .05$  (Figure 2). Furthermore, whereas the likelihood of selecting from the riskier deck was significantly lower than chance in the life domain ( $M = 36\%$ ,  $SD = 15$ ),  $t(15) = -3.39, p < .01$ , it did not differ from chance in the cash domain ( $M = 45\%$ ,  $SD = 12$ ),  $t(15) = -1.81, ns$ .

Overall, there was no difference in the rate of switching between the two decks (on consecutive trials) between the life (41%) and cash domains (43%),  $\chi^2(1, N = 1,536) = .54, ns$ . However, as predicted, participants were more sensitive to loss in the life domain than in the cash domain. Specifically, when choices from the uncertain deck were followed by negative feedback (i.e., selecting from the certain deck would have yielded a better outcome), participants exhibited a tendency to switch to the certain deck on the subsequent trial, but this tendency was only observed in the life domain, binomial test,  $p$

< .001 (Figure 3). Stated differently, when selecting from the uncertain deck, participants were more likely to employ a *win-stay-lose-shift strategy* (e.g., Messick, 1967; Nowak & Sigmund, 1993) in the life domain than in the cash domain, staying with the risky option if it yielded a positive result on the previous trial and shifting to the sure option if it did not.

Skewness and kurtosis analyses demonstrated that the distribution of reaction time (RT) data did not deviate from normality (both  $ps > .05$ ). Overall, there was no significant difference in RT for choices made in the life ( $M = 863$  ms,  $SD = 247$ ) and cash ( $M = 810$  ms,  $SD = 374$ ) domains,  $t(15) = 1.01$ , ns. However, focusing on choices made from the uncertain deck revealed a significant interaction. Specifically, in the life domain, when choices made from the uncertain deck on trial  $n$  were followed by negative feedback, RT increased significantly (compared to trial  $n$ ) on trial  $n+1$ ; in contrast, in the cash domain, when choices made from the uncertain deck on trial  $n$  were followed by negative feedback, RT decreased significantly (compared to trial  $n$ ) on trial  $n+1$ ,  $F(1, 15) = 8.08$ ,  $p < .05$ . We attribute the longer response latency subsequent to receiving negative feedback on choices made from the uncertain deck in the life domain to greater conflict (see Mandel & Vartanian, 2008).

*fMRI*. Using an event-related design, we modeled regressors corresponding to fixation, choice, motor response, and feedback within each trial. Although incorporated into the design, the presentation of the fixation and the motor response were modeled out of the analyses by assigning null weights to their corresponding regressors. The analyses reported here concern neural activation in relation to the choice and feedback time points. We tested our two key neural hypotheses by investigating the direct contrast between the

two domains when subjects made choices between decks. As predicted the dorsal striatum, specifically the anterior caudate nucleus ( $\square 12, 18, 4, z = 3.45$ ), was activated more in the life domain than in the cash domain (Figure 4). Contrary to our prediction, we failed to observe activation in the OFC in the life–cash contrast. However, as predicted, the posterior insula (bordering on secondary somatosensory cortex, SII) ( $58, 14, 6, z = 3.23$ ) was activated more in the cash domain than in the life domain (Figure 4). Finally, contrary to our prediction we did not observe activation in the ACC or the anterior insula in the cash–life contrast.

To rule out that the activations observed in the above two contrasts (i.e., lifecash and cashlife) were driven by risk aversion rather than the manipulation of context, we recalculated the analyses, this time entering each participant’s risk score (i.e., percentage selection from the risky deck) as a covariate. The results continued to show that the anterior caudate nucleus ( $12, 18, 4, z = 3.41$ ) was activated more in the life domain than in the cash domain, and that the posterior insula (bordering on SII) ( $58, 14, 6, z = 3.14$ ) was activated more in the cash domain than in the life domain.

Following the results of the behavioral analysis, we explored the neural underpinnings of loss sensitivity in two further analyses. Given that these analyses were not conducted based on *a priori* ROI, we report activations that survived a whole-brain voxel-level intensity threshold of  $p < .001$ , uncorrected for multiple comparisons. First, behavioral results had shown that when choices from the uncertain deck were followed by negative feedback, participants exhibited a tendency to switch to the certain deck on the subsequent trial, but only in the life domain (Figure 3). Focusing specifically on choices from the uncertain deck, an analysis of the fMRI data demonstrated that choosing

the uncertain deck on trial  $n$  following negative feedback on trial  $n-1$  was associated with relatively higher activation in the dorsal hippocampus (bordering on posterior amygdala) (30, 16, 10,  $z = 3.60$ ) in the life than cash domain (Figure 5). The reverse contrast did not reveal any significant area of activation.

Second, an analysis of response latency demonstrated that participants were slower to respond following negative feedback in the life domain. Therefore, we investigated differences in the neural response to negative feedback as a function of domain. The results demonstrated that there was greater activation in the subgenual anterior cingulate (12, 26, 21,  $z = 3.92$ ) when participants received negative feedback in the life than cash domain (Figure 7). The reverse contrast did not reveal any significant area of activation. Furthermore, when feedback was positive, there was no difference in the neural response between the two domains (in either direction).

### Discussion

Our results are novel in highlighting dissociable and context-dependent neural systems underlying choice under conditions of uncertainty. Specifically, our results characterize the neural system implicated in decisions whose consequences are valued in terms of life or death, as opposed to cash. We observed greater activation in the anterior caudate nucleus when participants made choices in the life than cash domain, which we attribute to the greater intrinsic value attached to lives than cash. According to the “actor-critic” model, the ventral striatum (“the critic”) is involved in the formation of predictions about expected future rewards, whereas the dorsal striatum (“the actor”) acts on those learned predictions to maximize long-term reward (O’Doherty, 2004; O’Doherty et al.,

2004; see also Wrase et al., 2007). In fact, representations of contextual cues in the dorsal striatum may act as signals for action selection (Delgado et al., 2003, 2004).

It could be argued that the engagement of the caudate nucleus is due to risk aversion rather than the contextual manipulation per se (see Figure 2). However, two lines of evidence contradict this interpretation. First, our analysis which controlled for participants' risk aversion did not alter the results, demonstrating that the activation in the caudate nucleus is not a function of risk aversion. Second, attributing the involvement of the caudate nucleus to risk aversion would also be inconsistent with the available evidence regarding the neural basis of risk aversion. Notably, it is the anterior insula and not the striatum that has been shown reliably to underlie the neural representation of expected risk in financial decision-making tasks (Knutson & Bossaerts, 2007; Knutson & Greer, 2008; Kuhnen & Knutson, 2005).

Of course, the valuation of human lives is invariably tied to moral considerations (see Li, Vietri, Galvani, & Chapman, 2010). Evidence from moral psychology research has demonstrated that engagement in tradeoffs involving lives can influence choice and its underlying neural systems. For example, dilemmas that force participants to commit a moral violation regardless of the chosen option increase conflict in decision making—as measured by response latency (Greene, Nystrom, Engell, Darley, & Cohen, 2004; Greene, Sommerville, Nystrom, Darley, & Cohen, 2001). Such dilemmas activate a network of regions involved in conflict detection (anterior cingulate), negative emotion (insula), and cognitive control (middle frontal gyrus). However, dilemmas used in that literature pit two *certain* options against each other, whereas our participants made

choices under uncertainty. Our results suggest that the level of certainty associated with outcomes may influence choices and their neural correlates.

In contrast to life problems, the posterior insula (bordering on SII) was activated relatively more in cash problems. We argue that in the cash domain, maximization of earnings is key. In turn, to maximize earnings one must engage in optimal risk prediction and probability signaling. Recently a large literature has highlighted the role of the anterior and posterior insula in both processes (d'Acremont et al., 2009; Carlsson et al., 2006; Clark et al, 2008; Montague & Lohrenz, 2007; Preuschoff et al., 2008; Weller et al., 2009). Our results contribute to the growing literature on the role of the posterior insula in risk prediction and probability signaling.

In the subsequent analysis we observed that when risk-seeking choices received negative feedback, opting to return to the risky option was associated with relatively higher activation in the dorsal hippocampus in the life domain than in the cash domain (Figure 5). Reinforcement learning paradigms have shown a functional dissociation between the amygdala and hippocampus in fear conditioning. The amygdala is activated in encoding stimulus-response contingencies as a function of outcome. For example, in fear conditioning paradigms the amygdala is activated more in the early phase of conditioning as it encodes stimulus-outcome contingencies, after which it disengages and other regions take over to direct action as a function of encoded associations (Marschner, Kalisch, Vervliet, Vansteenwegen, & Büchel, 2008). In contrast, rather than encoding contingencies early on, the hippocampus is involved in the formation of context-dependent memories about stimulus-outcome associations (Hasler et al., 2007). In fact, in fear conditioning and extinction paradigms, activation in the hippocampus is correlated

positively with the magnitude of extinction memory (Milad et al., 2007). Our results demonstrate that context affects the link between decision outcomes and subsequent decisions, as risk-seeking choices following negative outcomes in the life domain are associated with relatively higher activation in the hippocampal system.

Shifting focus to outcome evaluation, the subgenual anterior cingulate was activated more when participants received negative feedback in the life domain than cash domain (Figure 6). This region is sensitive to receiving negative feedback that occurs in a “social” context—namely, one involving interactions between two humans rather than a human and a computer (van den Bos, McClure, Harris, Fiske, and Cohen, 2007). Our results suggest that the context of saving human lives may be sufficient for activating the subgenual anterior cingulate in the face of negative feedback.

The involvement of the subgenual anterior cingulate may also be due to its role in the experience of emotion, more generally. Not only do lesions to the subgenual cingulate cause an inability to experience emotion (Damasio, Tranel, & Damasio, 1990), but regional cerebral blood flow in the subgenual cingulate is reduced in depressed patients (Drevets et al., 1997). Our results suggest that the context in which negative feedback occurs can modulate the activation of regions that respond to emotion, thus extending the neural signatures of context effects to responses to outcomes as well as choice.

### Conclusion

Recently, Rangel et al. (2008) have argued for the involvement of five basic computations in value-based decision making: representation, valuation, action selection, outcome evaluation, and learning. Each computation is served by a specific configuration of brain structures, although certain structures serve more than a single computation. Our

findings suggest that contrasting choices made in the domains of life and cash can exert an influence on valuation, with subsequent effects downstream on action selection, outcome evaluation, and learning. As such, they extend the behavioral literature on the context-dependent nature of decision making by clarifying the computations that are susceptible to context manipulations.

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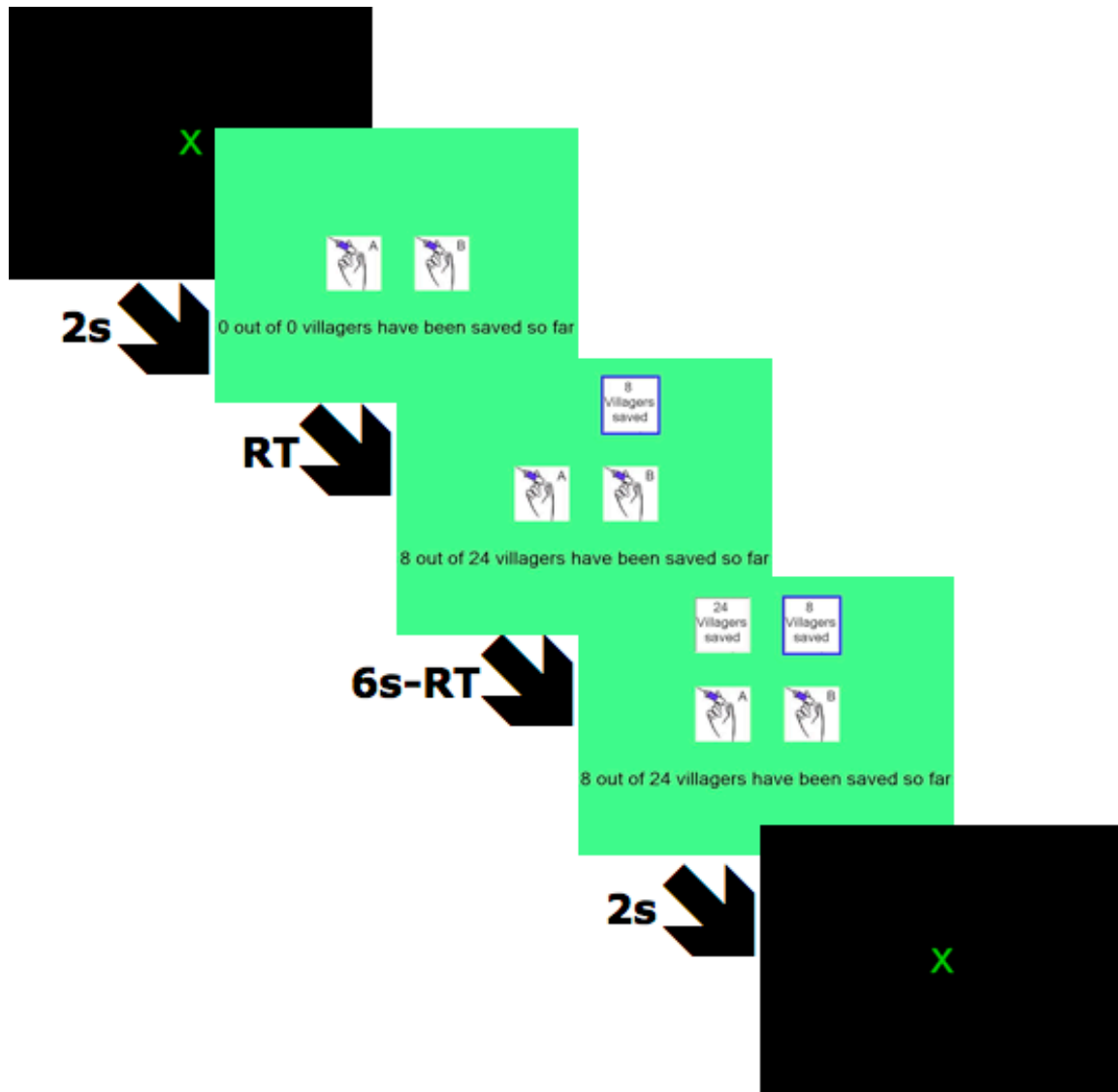
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### Author Notes

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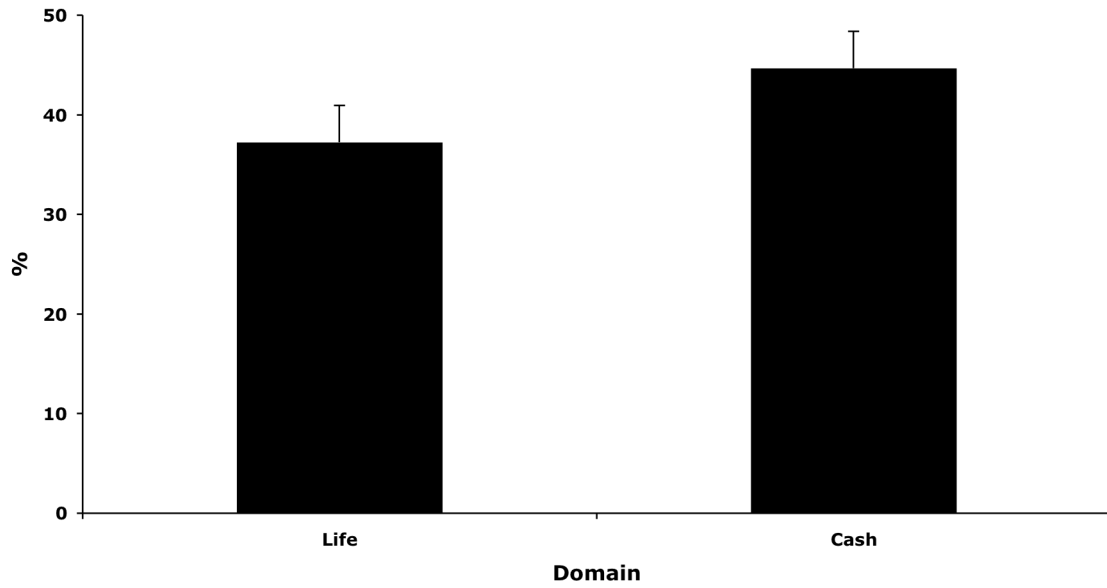
Figure 1



*Figure 1.* A trial from the task.

*Note.* The figure represents the first trial from a life block involving selection from the certain deck followed by feedback. In the equivalent cash trial the feedback would have been “\$800 out of \$2,400 have been saved so far.”

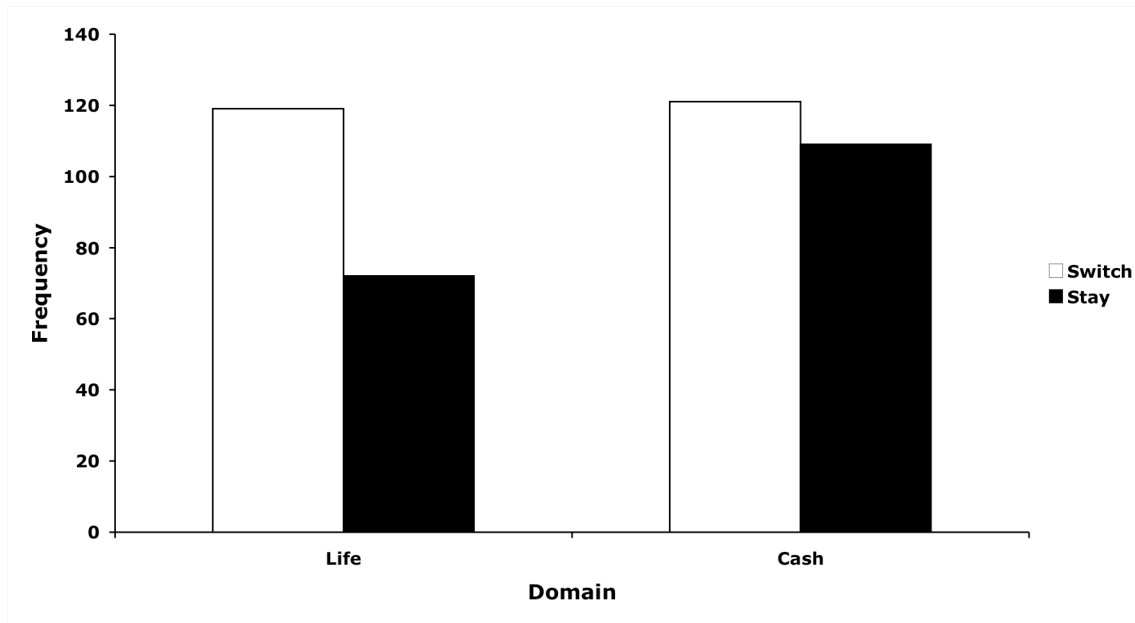
Figure 2



*Figure 2.* Selection from uncertain deck as a function of domain.

*Note.* Bars represent standard errors of measurement (SEM).

Figure 3



*Figure 3.* Choice strategy as a function of domain.

*Note.* The data represent frequency of choices that were made following the reception of negative feedback on the uncertain deck (see text).

Figure 4

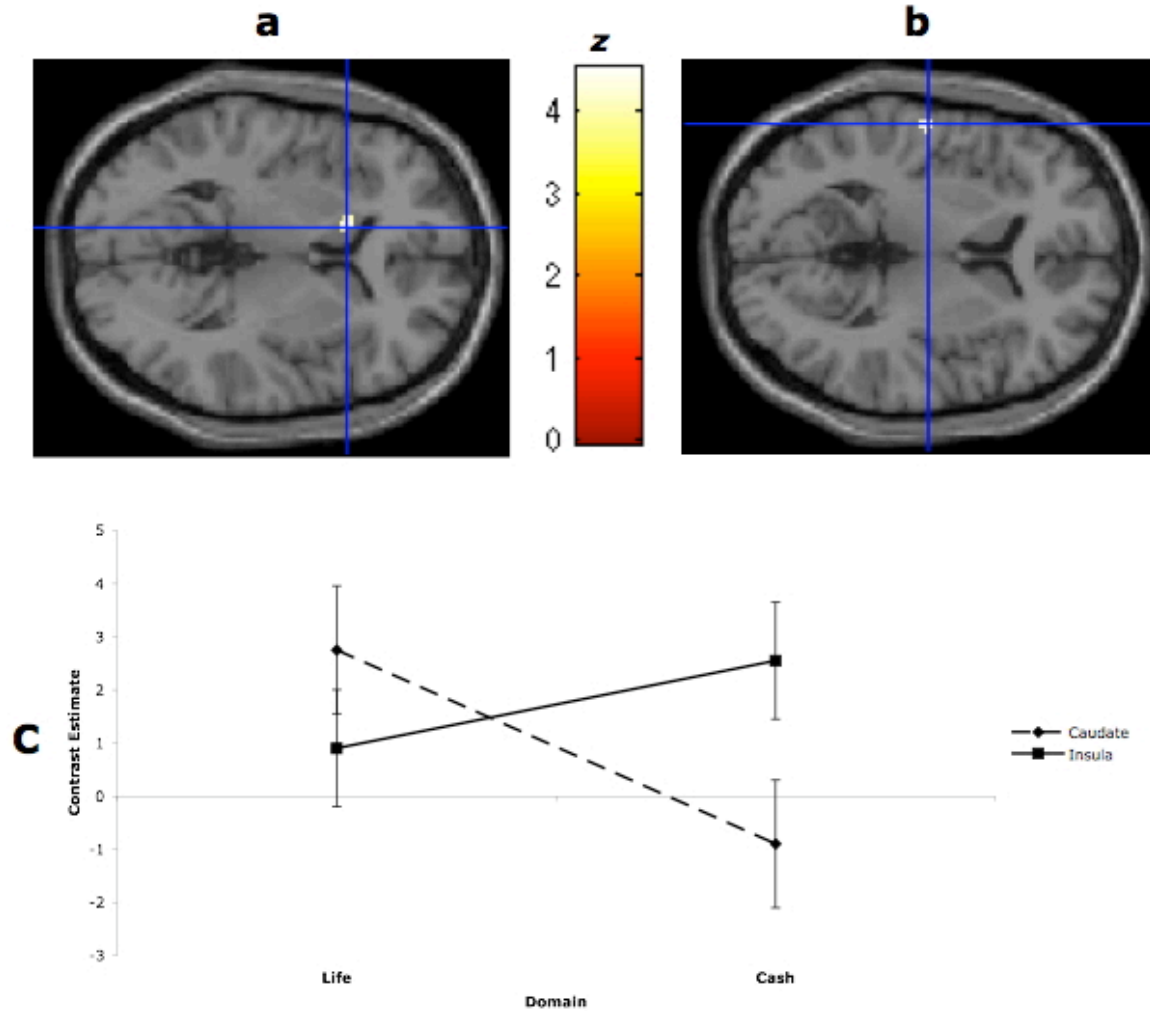
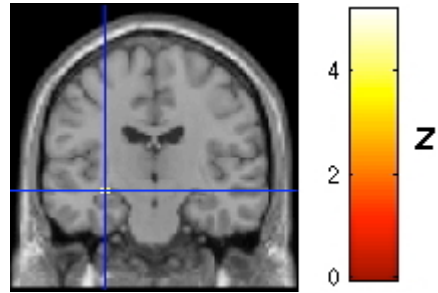


Figure 4. Neural activation for choice as a function of domain.

*Note.* (a) The anterior caudate nucleus was activated more when making choices in life problems. (b) The posterior insula (bordering on SII) was activated more when making choices in cash problems. (c) Condition specific parameter estimates demonstrate the activation of the anterior caudate nucleus and the posterior insula in life and cash problems. Bars represent 90% confidence intervals. SPMs rendered into standard stereotactic space and superimposed on to transverse MRI in standard space.

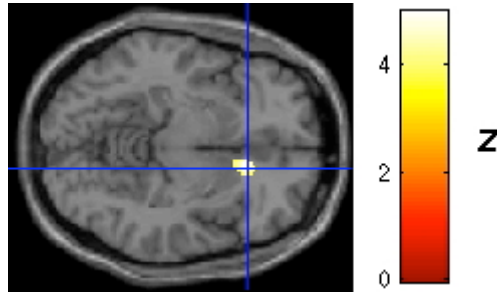
Figure 5



*Figure 5.* Neural activation as a function of negative feedback, subsequent choice, and domain.

*Note.* The dorsal hippocampus (bordering on posterior amygdala) was activated more in the life than cash domain when participants opted to return to the uncertain deck on trial  $n$  following negative feedback on trial  $n-1$ . SPM rendered into standard stereotactic space and superimposed on to coronal MRI in standard space.

Figure 6



*Figure 6.* Neural activation as a function of negative feedback and domain.

*Note.* The subgenual anterior cingulate was activated more when participants received negative feedback in the life domain than when they received negative feedback in the cash domain. SPM rendered into standard stereotactic space and superimposed on to transverse MRI in standard space.