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Sebastian Lehmann/Martin Reimann

OTTO VON GUERICKE
UNIVERSITÄT
MAGDEBURG

FACULTY OF ECONOMICS
AND MANAGEMENT

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Sebastian Lehmann[1*], Martin Reimann[2]

[1] Otto-von-Guericke-University, Magdeburg, Germany
[2] University of Southern California, Los Angeles, California, USA

Sebastian Lehmann
Otto-von-Guericke-University
Department of Marketing
Magdeburg, Germany 39106
Phone: +49 (391) 6711019
E-mail: sebastian.lehmann@ovgu.de

Martin Reimann
University of Southern California
Department of Psychology / Brain & Creativity Institute
Los Angeles, California 90089
Phone: +1 (213) 740-8528
E-mail: mreimann@usc.edu

* Corresponding author

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Abstract

"Time is money" is how a common saying goes, reflecting a widespread assumption in many people's everyday life. It seems that money and time are very similar concepts which might even be exchangeable all together. However, the neurophysiological processes underlying the activation of time or money are not yet completely understood. In order to understand in how far and in which dimensions the concept of time versus the concept of money effects human behavior we enquired the neural differences of the time versus money effect. This paper broadens the understanding of both concepts and investigates the posited distinct mindsets of time and money using functional magnetic resonance imaging (fMRI) technology. A sample of 44 right-handed adults has been analyzed. Our data supports the idea of the existence of two distinct mindsets for time and money. However, contrasting both conditions in one general linear model only a few significant differences have been found. The insula seems to be a crucial locus for the neural difference of both mindsets. Higher insula activation in the time condition suggests stronger urge for the product primed with time.

Keywords

Acknowledgements

1   Introduction

Benjamin Franklin (1748/1961) once wrote: "Remember time is money," suggesting that both concepts are economically equivalent (Becker, 1965; Okada and Hoch, 2004; DeVoe and Pfeffer, 2007). Yet, in psychological terms, time and money seem to be quite different. Several investigations have provided evidence that the concepts of "time" and "money" alter behavior in different ways. For example, Saini and Monga (2008) showed that decision making is more heuristic in situations that require spending time than in situations that involve spending money. The authors argued that heuristics are used more for time because consumers' time expenditures are harder to account for than those for money. Liu and Aaker (2008) explored the behavioral consequences of time compared to money in the context of charitable giving, showing that asking for time first (i.e., the "time-ask"), compared to asking for money first (i.e., the "money-ask"), increases the subsequent amount of money donated to the charity. The authors argued that time and money each may have activated a mindset that is different from the other: while thoughts of spending time for the charity may have activated a more emotional mindset, in which collective motives, goals of emotional well-being, and beliefs of personal happiness became salient, thoughts of giving money to the charity could have activated a value-maximization mindset that separated the donor from the charity psychologically and decreased beliefs of personal happiness. Building on the "time-ask effect," Mogilner and Aaker (2009) revealed a "time-versus-money effect," in which a time prime led to more favorable product attitudes. The authors contended that the activation of the concept of time (versus money) increased the focus on product experiences (versus product possessions) and, thus, augmented a personal connection between consumer and product. This connection, in turn, improved attitudes towards the product, increased the willingness-to-pay for the product, and influenced consumers' decisions to actually buy the product.

While prior research has made progress in increasing the understanding of the differential behavioral effects of time versus money, the psychological and neurophysiological underpinnings of priming consumers with time compared to those of priming them with money are much less clear. For example, while Liu and Aaker (2008) argued that priming time leads to an emotional mindset while priming money triggers a value-maximization mindset, other investigators have provided some opposing evidence. In particular, Dunn et al. (2008) showed that spending money on others as compared to spending it on oneself promotes happiness, which indicates the involvement of an emotional mindset rather than to a value-maximization one. As such, it is necessary to shed more light on the underlying neurophysiological mechanisms of time and money in order to understand *how* these concepts operate psychologically and differentially affect downstream behavior.

The present research utilizes functional magnetic resonance imaging (fMRI) to investigate the neurophysiological underpinnings of time primes versus money primes and their consequences for product evaluation. FMRI offers some methodological advantages over self-report measurement as it (1) permits interpretation of psychological processes in the brain as they are taking place, (2) enables measurement of nonconscious processes, and (3) allows for localization and differentiation of concepts that may seem subjectively similar but are actually processed differently (Shiv, 2007; Reimann et al., 2011). For the present research, these three advantages translate into the ability to pinpoint different activation patterns before, during, and after either time or money is primed; to detect processes that operate outside of participants' awareness; and to differentiate the processes underlying the two mindsets.

In this research, we replicate prior behavioral research (Mogilner and Aaker, 2009) by showing that merely mentioning "time" (compared to merely mentioning "money") leads participants to more positively evaluate products. More importantly, we provide novel insight into the neurophysiological underpinnings of time versus money by showing that these positive product evaluations in the time condition (as compared to the money condition) are preceded by increased activation in the insula. The insula (also referred to as the insular cortex or the insular lobe) is a brain area that has been found to be a crucial mechanism in diverse but related psychological phenomena such as urging and addiction (Naqvi and Bechara, 2009), loss aversion (Knutson et al., 2007; Knutson and Bossaerts, 2007), interpersonal love (Bartels and Zeki, 2000; Bartels and Zeki, 2004; Beauregard et al., 2009), and brand love (Reimann et al., 2012). These functions are conceptually closely related to Mogilner and Aaker's (2009) notion of a time-versus-money effect, which argues in favor of a greater personal connection between consumer and product right after time primes than right after money primes.

In the next section, we present the results of a content analysis on both the neurophysiological correlates and the psychological functions that underlie the concepts of time and money. Following this content analysis, we present an fMRI experiment in which participants engage in a behavioral product rating task while their blood oxygen level dependence (BOLD) responses are recorded.

2   The Neurophysiological Bases of Time and Money

The majority of studies that investigated the neurophysiological underpinnings of the concept of time have focused on time perception and internal time duration measurement. Using the keywords "fMRI," "time," "time perception," "time psychology," and "internal clock," Table 1 summarizes the results of a number of fMRI studies in which brain areas were identified for specific time-related functions. For example, previous investigations provided initial evidence for an association between time perception and increased activation of the insula (Craig, 2009; Wittmann, 2009; Wittmann and Van Wassenhove, 2009; Wittmann et al., 2010; Van Wassenhove et al., 2011). Other studies have identified several different brain areas in which time duration measurement may be processed, including the posterior parietal cortex (Bueti et al., 2008), the prefrontal cortex (Rubia and Smith, 2004; Lewis and Miall, 2006), and the fronto-striatal circuits (Harrington et al., 2004; Hinton and Meck, 2004). In summary, the concept of time and time-related phenomena (e.g., time perception) have been associated with activation changes in the prefrontal cortex (we identified ten studies); the insula, parietal cortex, and putamen (five studies each); the caudate, frontal gyrus, operculum, striatum, and temporal gyrus (three studies each); the parietal lobule and the supplementary motor area (two studies each) as well as the cingulate cortex, cerebellum, declive, hippocampus, intraparietal sulcus, orbitofrontal cortex, parahippocampus, precuneus, semilunar lobule, sensorimotor cortex, supra-marginal gyrus, and thalamus (one study each).

Insert Table 1 here

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The neurophysiological underpinnings of the concept of money have been subject to far more studies than those of time. Using the keywords "fMRI," "money," "money perception," and "money psychology," Table 2 summarizes the results of several fMRI studies in which brain areas were identified for money-related functions. For example, it was found that the mere anticipation of monetary gains activates the ventral and dorsal striatum, anterior thalamus, anterior insula, cortical motor regions, and the cerebellar vermis (Knutson et al., 2003). Furthermore, the ventral striatum and the insula have been implicated mainly in the processing of concrete monetary rewards (Kuhnen and Knutson, 2005). Another investigation revealed that (1) fronto-parietal regions (i.e., regions of the lateral prefrontal cortex and posterior parietal cortex) elicit greater activation for delayed monetary rewards, (2) limbic and paralimbic cortical structures (i.e., the ventral striatum, medial prefrontal cortex, and posterior cingulate cortex) reveal greater activation for immediately available rewards, and (3) that fronto-parietal regions show greater activation for both immediate and delayed monetary rewards (McClure et al., 2004). In summary, the concept of money and money-related phenomena (e.g., monetary reward) have previously mainly been related to activation changes in the prefrontal cortex (we identified eight studies); the cingulate cortex, nucleus accumbens (seven studies each); the insula, striatum, and thalamus (six studies each); the amygdala, dorsal caudate, and frontal cortex (five studies each); the orbitofrontal cortex (four studies); the midbrain and putamen (three studies each); the frontal gyrus, globus palladus, parietal lobule, and precuneus (two studies each) as well as the cerebellar vermis, cerebellum, frontal pole, fusiform gyrus, hippocampus, hypothalamus, operculum, medial temporal lobe, motor cortex, orbital gyrus, and the precentral gyrus (one study each).

Insert Table 2 here

While these studies provide interesting insights into the neurophysiological processes underlying either time or money, to our knowledge no previous study has directly compared the neurophysiology of time with that of money. Following prior behavioral research on the time-versus-money effect in product evaluations (Mogilner and Aaker, 2009), we would expect a greater emotional mindset for time primes than for money primes, because the concept of time seems to boost the formation and maintenance of close personal connections between consumer and product to a greater extent than a money mindset. Specific brain areas have been associated with emotional processing in prior research (Bechara and Damasio, 2005; Reimann and Bechara, 2010; Reimann and Zimbardo, 2011). The aforementioned content analysis identified several of these emotional brain areas, including the insula, the amygdala, and parts of the prefrontal cortex.

But, why should either time or money be associated with a higher degree of activation in these emotional brain regions? Both money (Dunn et al., 2008; Vohs et al., 2008) and time (Sheldon and Elliot, 1999; Mogilner, 2010) can foster well-being and elicit an emotional mindset, and can, therefore, lead to stronger urgings to recreate or maintain this state. Indeed, money can possess a drug-like character (Roll et al., 2000; Lea and Webley, 2006), which may explain why people have an urge for it. On the other hand, it has been argued that time has greater emotional meaning than money (Mogilner and Aaker, 2009) and that money even weakens the emotional link to objects as well as to people (Vohs et al., 2006; 2008; Liu and Aaker, 2008). Further, when asked to think about travelling back in time, people tend to forget about negative aspects from their past and instead remember positive situations and feelings (Carstensen et al., 2000), as if they have an urge for the "good old times." As such, when primed with time (versus money),

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reminders of positive feelings might elicit a stronger emotional mindset, lead to a higher degree of urging to recreate or maintain this emotional state, and positively influence downstream product attitudes.

In particular, one brain area has been associated with these functions—that is, urging and processing feelings of personal connectedness. For several decades, research in functional neuroanatomy has held that the insula is crucial in the integration of bodily information into emotional and motivational functions (Mesulam and Mufson, 1982). Humans perceive feelings from their bodies, which are fed into an afferent neural system that represents all aspects of the physiological condition of the physical body (Craig, 2002). For example, perceiving facial expressions ranging from sad to happy can trigger bodily responses, which in turn are associated with insula activation (Britton et al., 2006). Subsequently, the insula integrates these bodily states into conscious feelings and decision-making processes (Bechara and Damasio, 2005; Reimann and Bechara, 2010; Reimann and Zimbardo, 2011). The insula has also been shown a crucial brain region in urging and addiction (Naqvi and Bechara, 2009) as well as—in more applied domains—in loss aversion (Knutson et al., 2007; Knutson and Bossaerts, 2007), interpersonal love (Bartels and Zeki, 2000; Bartels and Zeki, 2004; Beauregard et al., 2009), and brand love (Reimann et al., 2012). These investigations provide compelling evidence on certain insula functions that conceptually map the psychological functions of the time-versus-money effect. As a word of caution, however, we acknowledge that like most prior cognitive neuroscience research, the present study relies on reverse inference in that activation of a particular brain area (insula) is interpreted as support for engagement of particular psychological processes (urging, personal connection). In dealing with this issue, we followed the recommendations by Poldrack (2006) and reported task characteristics and showed replication of prior behavioral evidence. Yet, we recognize that the breath of functions associated with the insula leave room for interpretation. As such, one can only hold the insula responsible for its most basic function—that is, integration of bodily information into emotional and motivational functions (Mesulam and Mufson, 1982) beyond which the particular process becomes less clear.

3 Materials and Methods

The present experiment investigates the question of whether the activation of the concept of either time or money leads to distinct neurophysiological responses, which in turn may help to explain behavioral differences in how consumers evaluate products. On the basis of Mogilner and Aaker's (2009) research, we designed a behavioral product rating task in which participants engaged in product evaluations while undergoing fMRI.

3.1 Participants

Forty-four right-handed, healthy subjects (23 females; M_{age} = 24.8 years, SD_{age} = 4.0 years; ranging from 20 to 44 years) participated in the study for a compensation of 15 euro. Participants were recruited from the neuroscience subject pool of a public university. The study was approved by the university's ethics committee, participants were screened for medical eligibility, and written informed consent was obtained from each participant prior to the experiment. Because we focused on a specific product, participants were also asked whether they had bought their current wristwatch themselves. Those participants that indicated they had bought their watch were selected for the study and asked to take a picture of their watch and send it in. Each picture was taken with the watch in the center in front of a neutral background. Participants were randomly

assigned to one of two conditions in this between-by-within experimental design. In one condition, participants were primed with the concept of time; in the other condition, participants were primed with the concept of money. One participant was excluded from subsequent data analyses because of extensive head motion during the brain scan.

3.2   Scan Preparation and Behavioral Task

Before entering the brain scanner, participants underwent a short training version of the task to alleviate task-related confusion. Next, participants received the initial prime. We employed two established priming techniques (Strack et al., 1985; Dunn and Schweitzer, 2005; Lee et al., 2009), one outside the brain scanner and one inside the brain scanner. Outside the brain scanner, participants were given five minutes to write about anything that came to their minds when thinking about one of the two concepts. Inside the brain scanner, word primes that aimed at inducing one mindset or the other were given visually (Burnham, 2000; Bargh et al., 2001; Mogilner et al., 2008; Mogilner and Aaker, 2009). Participants were each placed supine inside a full-body 3.0 Tesla Siemens Magnetom Trio scanner (manufactured by Siemens AG in Erlangen, Germany) fitted with a 12-channel matrix head coil. Participants were presented with the full version of the product-rating task while resting on their backs. Task stimuli were projected into the scanner; participants could see the stimuli in a mirror located directly before their eyes. The task consisted of fifteen trials with five phases each to generate a sufficient number of volumes for the neuroimaging data analyses. For presentation of the task stimuli and accurate recording of participants' product ratings, E-Prime Professional software, version 2.0.8.74 (manufactured by Psychology Software Tools Inc. in Pittsburg, Pennsylvania) was used.

Each participant saw a series of seven word primes (presented for ten seconds each). In the time condition, participants saw *time*, *to have time*, *win time*, *time management*, *enjoy time*, *use time*, and *time* again. In the money condition, participants were shown *money*, *to have money*, *win money*, *money management*, *enjoy money*, *use money*, and *money* again. It is important to note that we used words and phrases representing the general concepts of time and money rather than a specific amount of time or a specific monetary possession. In summary, in our study, we activated the concepts of either time or money through the use of mental priming techniques, which heightened the salience of either time or money at a level below participants' conscious awareness. Thus, priming acted as a nonconscious reminder of both concepts (Vohs et al., 2006a, Liu and Aaker, 2008; Mogilner and Aaker, 2009).

The initial word priming was followed by the behavioral rating task, which consisted of a repeated five-step trial (Figure 1). First, for eight seconds, participants were asked either "*How much Time have you spent on your wristwatch?*" or "*How much Money have you spent on your wristwatch?*" ("priming phase"). Second, for ten seconds, participants were prompted to think about the product with the question "*What comes to your mind when thinking of your wristwatch?*" ("thinking phase"). During this phase, participants were also shown the picture of their own wristwatch. Third, for four seconds, participants were told to prepare themselves to rate their wristwatch ("preparation phase"). Fourth, for four seconds, participants rated their wristwatch on a 5-point Likert-type semantic differential scale from unfavorable to favorable by pressing one of five buttons on a response box ("rating phase"). The lowest possible rating was given with the thumb of the right hand and consecutive higher ratings were given with the next finger going to the right. Fifth and finally, a fixation cross appeared for three seconds and ended each trial ("fixation phase") before the next trial started. The task timing was in line with previous research on mood and emotion induction (e.g., Isen et al., 1976; Isen and Gorgoline,

1983). The trial was repeated three times. Blood-oxygen level-dependent (BOLD) signal changes were recorded during the whole task.

Insert Figure 1 here

3.3 Neuroimaging Data Collection

We applied standard neuroimaging procedures (e.g., Reimann et al., 2010; Kable, 2011; Reimann et al., 2011). For anatomical neuroimaging, we ran (1) a brief scan for land-marking and (2) a high-resolution whole-brain magnetization-prepared rapid gradient-echo (MPRAGE) sequence. MPRAGE sequence parameters were: echo time (TE)/repetition time (TR)/inversion time (TI) = 4.77/2,500/1,100 ms, flip angle = 7°, matrix = 256 x 256, field of view (FOV) = 256 mm, slice thickness = 1 mm without gap. For functional neuroimaging, a time series of 130 volumes with 34 slices in the sagittal plane was collected in an interleaved sequence, using single-shot gradient-echo planar imaging (TR = 2,000 ms, TE = 30 ms, flip angle = 80°, resolution = 3.5 mm x 3.5 mm x 3.5 mm, and FOV = 224 mm, 64 x 64 matrix) and allowing for whole-brain coverage in a relatively short period of time. Participants were given earplugs to reduce the distraction of scanner noise and participants' head movements were minimized with foam pads.

3.4 Neuroimaging Data Analysis

For the neuroimaging data analysis, BrainVoyager QX software, version 2.3 (manufactured by Brain Innovation B.V. in Maastricht, The Netherlands) was used. A number of preprocessing steps were performed on the functional data prior to the statistical analysis. For each participant, we used standard methods of analysis (e.g., DeBettencourt et al., 2011; Hammer et al., 2011), including: (1) exclusion of the first three scans per run from the analysis to ensure that steady-state tissue magnetization was reached and, therefore, to permit T1-equilibration effects; (2) incremental linear trend removal to eliminate scanner-related signal drifts; (3) temporal high-pass filtering to remove temporal frequencies (i.e., scanner- and physiology-related noise) lower than three cycles per run; and (4) a rigid-body algorithm, which rotates and translates each functional volume in three-dimensional space in order to correct for small head movements between scans. The data was spatially smoothed with a three-dimensional Gaussian filter (i.e., 4 mm full-width at half maximum). Functional neuroimages were co-registered to the anatomical images and interpolated to cubic voxels. For anatomical orientation, the three-dimensional T1-weighted scans were used to overlay the statistical maps. To enable comparison among participants, both anatomical and functional volumes were spatially normalized into Talairach space (Talairach and Tournoux, 1988).

In line with prior priming and emotion induction research (e.g., Damasio et al., 2000) and because the study aimed at identifying the neurophysiological underpinnings of time versus money, we focused our analyses of the neuroimaging data on the "priming phase"; that is, those eight seconds in which participants were asked "*How much Time* [or: *Money*] *have you spent on your wristwatch?*" and right before participants rated the product more positively in the time condition than in the money condition. Blood oxygen level dependent (BOLD) responses during the time priming phase was directly compared to participants' BOLD responses during the money priming phase. This approach of directly comparing time with money conditions is not only following the analyses of behavioral data by Mogilner and Aaker (2009) but is also in line with

recent fMRI research, which directly compared different emotional states (e.g., Andersen et al., 2001) and different mindsets (e.g., Dietvorst et al., 2009) with each other.

First, we analyzed data on the single-subject level. Specifically, fixed-effects whole-brain general linear model (GLM) analyses were performed, using a regression model consisting of 14 predictors. A set of seven predictors corresponded to the specific phases of the task (i.e., an introduction phase, the first priming phase, and the five trial phases), while a set of seven confounding predictors captured motion-related artifacts and artificial activity within the ventricles (Weissenbacher et al., 2009). The BOLD signal change for each predictor was modeled by using a two-gamma hemodynamic response function (Friston et al., 1998).

Second, after creating statistical parametric maps for each participant by applying linear contrasts to the predictor estimates (i.e., beta weights), a random-effects GLM analysis was performed at the group level. At the group level, we employed a summary statistics approach, which uses the statistical maps computed at the single-subject level. This method takes the variability of effects across subjects into account, thus permitting population-level inferences. One between-subject factor (i.e., prime) with two levels (i.e., time and money) was generated to compare differences in activation for the predictor of interest (i.e., the "priming phase"). The global threshold was set to $p < .01$, uncorrected. Threshold maps were submitted to a region-of-interest-based correction for multiple comparisons. The correction criterion is based on Monte Carlo simulations calculating the likelihood of obtaining different cluster sizes. After 1,000 iterations, the minimum cluster size threshold that yielded a cluster-level false-positive rate of .05 was applied to the statistical maps (in our case seven voxel). Combined with relaxed single-voxel thresholds, this procedure will ensure a global error probability of $p < .05$ (Forman et al., 1995; Goebel et al., 2006).

Third, we compared predictors by performing a random-effects GLM analysis at regions of interest (e.g., Reimann et al., 2011). Regions of interests were defined both functionally and anatomically (Lancaster et al., 2000), and included both the right insula (at Talairach coordinates of x = 44, y = -26, z = 15) and the left insula (at Talairach coordinates of x = -31, y = -23, z = 18).

4   Results

4.1   Behavioral Results
Building on the results of Mogilner and Aaker (2009), we expected a higher favorability rating in the time condition. To test this hypothesis, we ran a one-tailed independent-samples *t*-test to analyze whether participants rated their wristwatches more favorable in the time condition than in the money condition. As expected, favorability was significantly greater in the time condition (M_{time} = 3.68, SD = .87) than in the money condition (M_{money} = 3.18; SD = 1.07), $t(42)$ = 1.69, $p < .05$. These results replicate the behavioral findings of Mogilner and Aaker (2009), who found that when consumers are primed with time, their favorability ratings for products increase.

4.2   Neuroimaging Results
Consistent with prior research (e.g., Knutson et al. 2001a; 2001b), we focused our analyses of the neuroimaging data on the trial phases in which emotional processes are most likely to operate: in our case, we concentrated on the actual priming phase. Contrasting BOLD responses during the time prime with BOLD responses during the money prime, whole-brain analysis results revealed

increased activation in the right insula ($t(42) = 3.39$, $p < .001$), the left insula ($t(42) = 4.18$, $p < .001$), and the medial temporal gyrus ($t(42) = 3.88$, $p < .001$). Figure 2 illustrates these activation changes, and Table 3 summarizes additional information, including Talairach coordinates and corresponding Brodmann areas. Further, we conducted a random-effects ROI analysis, focusing on activation changes in the insula. Results supported the findings from the whole-brain analysis, revealing greater activation in both the right insula ($t(42) = 3.53$; $p < .05$) and the left insula ($t(42) = 4.13$; $p < .05$) for time compared to money.

Insert Figure 2 and Table 3 here
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5   Discussion

The present research provides novel insight into the neurophysiological underpinnings of the time-versus-money effect. This investigation shows that priming subjects with time (compared to money) is associated with significantly greater activation in the insula (both in the left and right hemisphere of the brain) and leads to more positive product evaluations.

The finding from our neuroimaging experiment possibly explains the behavioral differences in product evaluations identified in previous research (Mogilner and Aaker, 2009) and replicated in this study. Because the time prime elicited a more emotional mindset (as became evident in increased insula activation—a limbic region) than the money prime, participants rated products as more favorable during the time prime than during the money prime. Because participants rated a product to which they had established a close relationship, the time prime could have increased such a feeling of closeness to the product, while the money prime could have decreased those feelings and possibly have triggered a feeling of distance. Indeed, previous behavioral work had indicated that money mindsets lead to greater physical distancing (Vohs et al., 2006).

Besides making important contributions to research on the time-versus-money effect, the present study also has some limitations, which in turn provide avenues for future research. Because the insula plays a role in many different emotional and motivational processes, the conceptual link between the identified neurophysiological processes and psychological phenomena such as urging or relationship closeness is not yet fully understood. Future research may, for example, implement manipulations of urgings during time and money priming to further investigate the identified effects.

Taken as a whole, this research speaks extensively to the diverse research community involved in research on time and money. Even though our research might raise a new set of questions, we believe that it may also provide meaningful answers on some of the psychological and neurophysiological differences between time and money.

Conflict of Interest Statement
The authors declare that this research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Figure and Tables
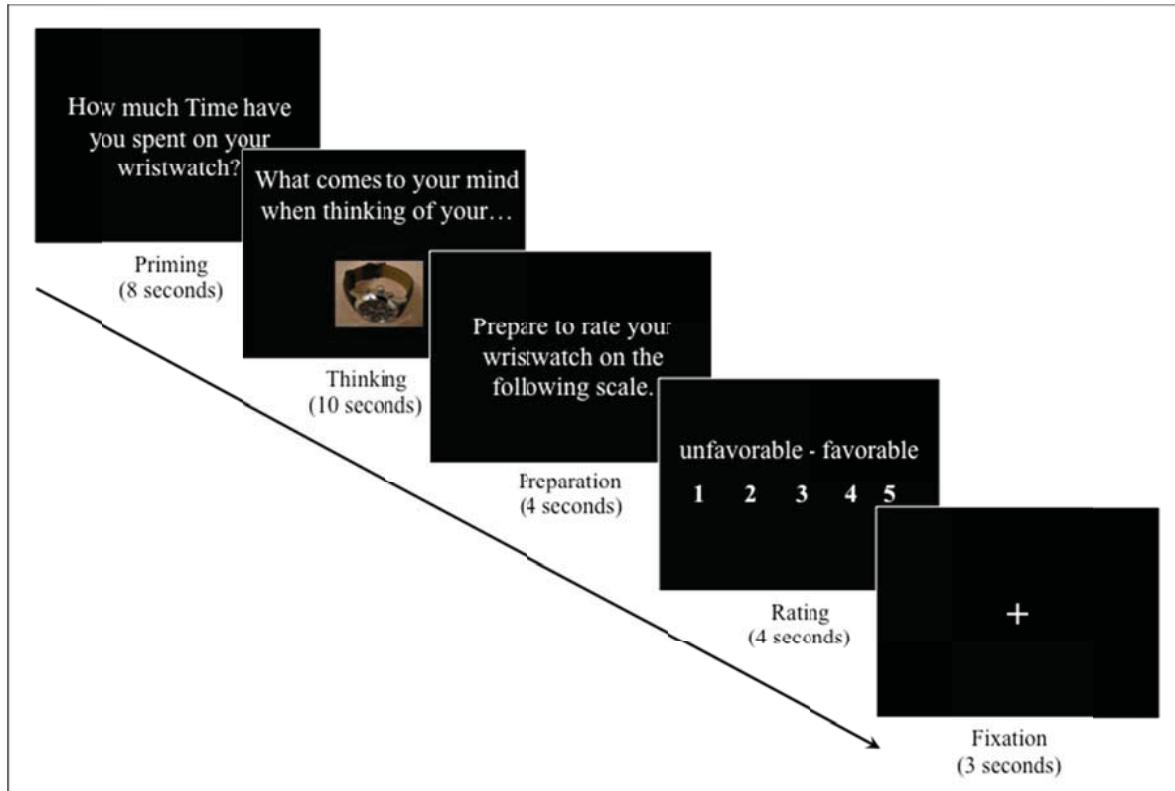
Figure 1   Product rating task
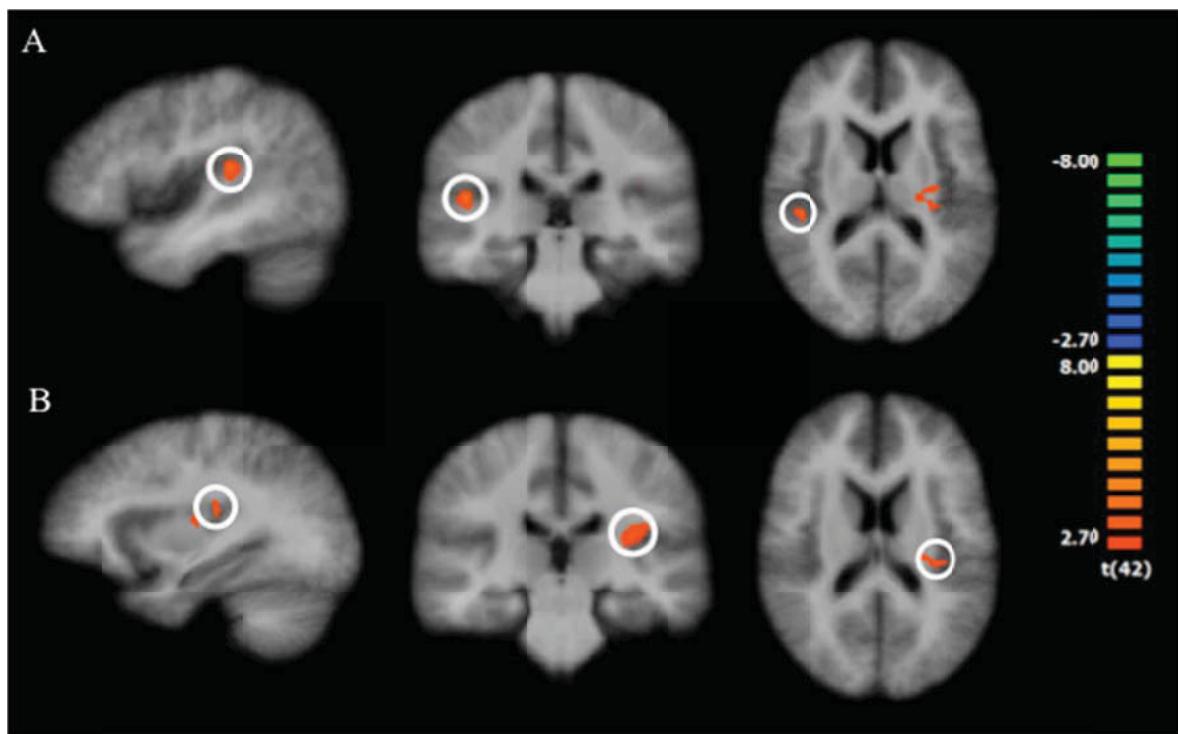
Figure 2 Significantly increased activation in the insula following the time prime compared to the money prime. Note: The color bar shows the *t*-values; colors from red to yellow indicate activation increases, and colors from blue to green indicate activation decreases. The insula is encircled. Panel A shows right insula activation differences during the "priming phase," and panel B shows left insula activation differences during the "priming phase."

Table 1 Brain areas linked to the concept of time

Selected brain areas	Author(s) (year)	Method	N	Focal topic	Result
Caudate	Harrington et al. (2004)	Time perception task (discrimination), fMRI	24	Timing, memory, interval encoding, decision making	Proposes that systems mediating interval encoding and decision processes are independent.
	Hinton and Meck (2004)	Timing task, fMRI	6	Time perception, interval timing	Shows involvement of the frontal–striatal circuitry in human interval timing.
	Jantzen et al. (2005)	Self-paced rhythmic timing task, fMRI	12	Stimulus modality and coordination pattern in rhythmic timing	Provides evidence that time and timing are served by a context-dependent distributed network rooted in basic sensorimotor processes.
Cerebellum	Harrington et al. (2004)	Time perception task (discrimination), fMRI	24	Timing, memory, interval encoding, decision making	Proposes that systems mediating interval encoding and decision processes are independent.
Cingulate cortex	Hinton and Meck (2004)	Timing task, fMRI	6	Time perception, interval timing	Shows involvement of the frontal–striatal circuitry in human interval timing.
Declive	Jantzen et al. (2005)	Self-paced rhythmic timing task, fMRI	12	Stimulus modality and coordination pattern in rhythmic timing	Provides evidence that time and timing are served by a context-dependent distributed network rooted in basic sensorimotor processes.
Frontal gyrus	Hinton and Meck (2004)	Timing task, fMRI	6	Time perception, interval timing	Shows involvement of the frontal–striatal circuitry in human interval timing.
	Jantzen et al. (2005)	Self-paced rhythmic timing task, fMRI	12	Stimulus modality and coordination pattern in rhythmic timing	Provides evidence that time and timing are served by a context-dependent distributed network rooted in basic sensorimotor processes.
	Livesey et al. (2007)	Time discrimination task, fMRI	10	Time duration discrimination	Suggests that the extent of the timing "network" is overestimated, only three small brain regions certain to be directly concerned with duration judgments.

			N		
Hippocampus	Harrington et al. (2004)	Time perception task (discrimination), fMRI	24	Timing, memory, interval encoding, decision making	Proposes that systems mediating interval encoding and decision processes are independent.
Insula	Lewis and Miall (2003)	Judging duration of stimuli task, fMRI	8	Time perception, neural clock	Suggests a variety of brain regions used for the measurement of both sub- and supra-second temporal durations.
	Lewis and Miall (2006)	Cognitive timing task, fMRI	8	Time perception, time measurement	Provides insight into the possible role of several brain regions in attentional processing and working memory during cognitive time measurement tasks.
	Livesey et al. (2007)	Time discrimination task, fMRI	10	Time duration discrimination	Suggests that the extent of the timing "network" is overestimated; only three small brain regions certain to be directly concerned with duration judgments.
	Jantzen et al. (2005)	Self-paced rhythmic timing task, fMRI	12	Stimulus modality and coordination pattern in rhythmic timing	Provides evidence that time and timing are served by a context-dependent distributed network rooted in basic sensorimotor processes.
	Wittmann et al. (2010)	Viewing visual events, fMRI	15	Subjective time dilation; temporal illusion	Proposes that activation of areas important for cognitive control and subjective awareness leads to temporal dilation illusion suggesting a relation of time perception and self-referential processing.
Intraparietal sulcus	Schubotz et al. (2000)	Visual and auditory rhythm monitoring Task, fMRI	20	Perception of temporal features of the environment	Proposes that equal brain areas responsible for time perception a planning and coordination of movements.
Operculum	Schubotz et al. (2000)	Visual and auditory rhythm monitoring Task, fMRI	20	Perception of temporal features of the environment	Proposes that equal brain areas responsible for time perception a planning and coordination of movements.

Region	Reference	Task/method	N	Keywords	Findings
	Coull et al. (2004)	Attention to time or color stimulus attributes task, fMRI	12	Subjective time perception, attention	Shows more accurate processing of temporal pulses throughout the stimulus duration by enhanced activity in functionally specialized brain regions due to increased time attention.
	Morillon et al. (2009)	Time estimation task, fMRI	17	Perception of time	Proposes a three-staged model of time estimation with a duplicated collating process and unique counting.
Orbitofrontal cortex	Hinton and Meck (2004)	Timing task, fMRI	6	Time perception, interval timing	Shows involvement of the frontal–striatal circuitry in human interval timing.
Parahippocampus	Harrington et al. (2004)	Time perception task (discrimination), fMRI	24	Timing, memory, interval encoding, decision making	Proposes that systems mediating interval encoding and decision processes are independent.
Parietal cortex	Lewis and Miall (2003)	Judging duration of stimuli task, fMRI	8	Time perception, neural clock	Suggests a variety of brain regions used for the measurement of both sub- and supra-second temporal durations.
	Pastor et al. (2004)	Time discrimination task, fMRI	14	Time discrimination	Proposes that the frontal brain areas play a key role in temporal processing of somatosensory events.
	Harrington et al. (2004)	Time perception task (discrimination), fMRI	24	Timing, memory, interval encoding, decision making	Proposes that systems mediating interval encoding and decision processes are independent.
	Jantzen et al. (2005)	Self-paced rhythmic timing task, fMRI	12	Stimulus modality and coordination pattern in rhythmic timing	Provides evidence that time and timing are served by a context-dependent distributed network rooted in basic sensorimotor processes.
	Morillon et al. (2009)	Time estimation task, fMRI	17	Perception of time	Proposes a three-staged model of time estimation with a duplicated collating process and unique counting.
Parietal lobule	Pastor et al. (2004)	Time discrimination task, fMRI	14	Time discrimination	Proposes that the frontal brain areas play a key role in temporal processing of somatosensory events.

Region	Study	Task/Method	N	Keywords	Findings
	Jantzen et al. (2005)	Self-paced rhythmic timing task, fMRI	12	Stimulus modality and coordination pattern in rhythmic timing	Provides evidence that time and timing are served by a context-dependent distributed network rooted in basic sensorimotor processes.
Precuneus	Harrington et al. (2004)	Time perception task (discrimination), fMRI	24	Timing, memory, interval encoding, decision making	Proposes that systems mediating interval encoding and decision processes are independent.
Prefrontal cortex	Lewis and Miall (2003)	Judging duration of stimuli task, fMRI	8	Time perception, neural clock	Suggests a variety of brain regions used for the measurement of both sub- and supra-second temporal durations.
	Hinton and Meck (2004)	Timing task, fMRI	6	Time perception, interval timing	Shows involvement of the frontal–striatal circuitry in human interval timing.
	Lewis and Miall (2006)	Cognitive timing task, fMRI	8	Time perception, time measurement	Provides insight into the possible role of several brain regions in attentional processing and working memory during cognitive time measurement tasks.
	Vallesi et al. (2009)	Visual discrimination task / fMRI	14	Time processing	Shows the critical role of the right dorsolateral prefrontal cortex to observe the strategically mediated behavioral effects in the variable foreperiod paradigm.
	Morillon et al. (2009)	Time estimation task, fMRI	17	Perception of time	Proposes a three-staged model of time estimation with a duplicated collating process and unique counting.
Premotor cortex	Schubotz et al. (2000)	Visual and auditory rhythm monitoring tasks, fMRI	20	Perception of temporal features of the environment	Proposes that equal brain areas responsible for time perception a planning and coordination of movements.
	Lewis and Miall (2003)	Judging duration of stimuli task, fMRI	8	Time perception, neural clock	Suggests a variety of brain regions used for the measurement of both sub- and supra-second temporal durations.
	Coull et al. (2004)	Attention to time or color stimulus attributes task, fMRI	12	Subjective time perception, attention	Shows more accurate processing of temporal pulses throughout the stimulus duration by enhanced activity in functionally specialized brain regions due to increased time attention.

Region	Reference	Task, method	n	Function	Description
	Pastor et al. (2004)	Time discrimination task, fMRI	14	Time discrimination	Proposes that the frontal brain areas play a key role in temporal processing of somatosensory events.
	Pouthas et al. (2005)	Long and short duration estimation task, fMRI	6	Time perception, interval estimation	Proposes the support of several brain areas to a clock mechanism, decision and response-related processes, and active maintenance of temporal information.
Putamen	Schubotz et al. (2000)	Visual and auditory rhythm monitoring Task, fMRI	20	Perception of temporal features of the environment	Proposes that equal brain areas responsible for time perception a planning and coordination of movements.
	Nenadic et al. (2003)	Perceptual timing task, fMRI	15	Time perception, internal clock	Proposes an interaction between brain areas with modality-dependent sensory cortical, timing-specific, and attention and memory function.
	Hinton and Meck (2004)	Timing task, fMRI	6	Time perception, interval timing	Shows involvement of the frontal–striatal circuitry in human interval timing.
	Jantzen et al. (2005)	Self-paced rhythmic timing task, fMRI	12	Stimulus modality and coordination pattern in rhythmic timing	Provides evidence that time and timing are served by a context-dependent distributed network rooted in basic sensorimotor processes.
	Livesey et al. (2007)	Time discrimination task, fMRI	10	Time duration discrimination	Suggests that the extent of the timing "network" is overestimated, only three small brain regions certain to be directly concerned with duration judgments.
Semilunar lobule	Schubotz et al. (2000)	Visual and auditory rhythm monitoring task, fMRI	20	Perception of temporal features of the environment	Proposes that equal brain areas responsible for time perception a planning and coordination of movements.
Sensorimotor cortex	Jantzen et al. (2005)	Self-paced rhythmic timing task, fMRI	12	Stimulus modality and coordination pattern in rhythmic timing	Provides evidence that time and timing are served by a context-dependent distributed network rooted in basic sensorimotor processes.

Region	Reference	Task	n	Topic	Description
Striatum	Schubotz et al. (2000)	Visual and auditory rhythm monitoring tasks, fMRI	20	Perception of temporal features of the environment	Proposes that equal brain areas responsible for time perception a planning and coordination of movements.
	Nenadic et al. (2003)	Perceptual timing task, fMRI	15	Time perception, internal clock	Proposes an interaction between brain areas with modality-dependent sensory cortical, timing-specific, and attention and memory function.
	Coull et al. (2004)	Attention to time or color stimulus attributes task, fMRI	12	Subjective time perception, attention	Shows more accurate processing of temporal pulses throughout the stimulus duration by enhanced activity in functionally specialized brain regions due to increased time attention.
Supplementary motor area	Schubotz et al. (2000)	Visual and auditory rhythm monitoring task, fMRI	20	Perception of temporal features of the environment	Proposes that equal brain areas responsible for time perception a planning and coordination of movements.
	Jantzen et al. (2005)	Self-paced rhythmic timing task, fMRI	12	Stimulus modality and coordination pattern in rhythmic timing	Provides evidence that time and timing are served by a context-dependent distributed network rooted in basic sensorimotor processes.
Supra-marginal gyrus	Livesey et al. (2007)	Time discrimination task, fMRI	10	Time duration discrimination	Suggests that the extent of the timing "network" is overestimated; only three small brain regions certain to be directly concerned with duration judgments.
Thalamus	Hinton and Meck (2004)	Timing task, fMRI	6	Time perception, interval timing	Shows involvement of the frontal–striatal circuitry in human interval timing.
Temporal gyrus	Hinton and Meck (2004)	Timing task, fMRI	6	Time perception, interval timing	Shows involvement of the frontal–striatal circuitry in human interval timing.
	Jantzen et al. (2005)	Self-paced rhythmic timing task, fMRI	12	Stimulus modality and coordination pattern in rhythmic timing	Provides evidence that time and timing are served by a context-dependent distributed network rooted in basic sensorimotor processes.
	Morillon et al. (2009)	Time estimation task, fMRI	17	Perception of time	Proposes a three-staged model of time estimation with a duplicated collating process and unique counting.

| Temporal sulcus | Morillon et al. (2009) | 17 | Perception of time | Time estimation task, fMRI | Proposes a three-staged model of time estimation with a duplicated collating process and unique counting. |

Note. Studies were sorted alphabetically by brain area and then chronologically within each brain area.

Table 2 Brain areas linked to the concept of money

Selected brain areas	Author(s) (year)	Method	N	Focal topic	Result
Amygdala	Breiter et al. (2001)	Gambling task, fMRI	12	Functional dissociation of experience and anticipation of rewards	Shows that responses to prospects and outcomes were generally, seen in the same regions. A common circuitry to the processing of diverse rewards is suggested.
	Knutson et al. (2001b)	Monetary incentive delay task, fMRI	9	Functional dissociation of reward anticipation and outcome	Shows differential recruitment of regions along the trajectory of ascending dopamine projections in reward anticipation and outcomes.
	Elliott et al. (2003)	Rewarded target detection task, fMRI	12	Functional distinction of value and magnitude	Shows different response of brain regions to the reward's value suggesting functional distinction in response patterns within a distributed reward system.
	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions.
	Spreckelmeyer et al. (2009)	Incentive delay task, fMRI	32	Men / women; monetary vs. social reward	Proposes that neural structures constituting the human reward system are proportionally activated for increasing levels of reward, independent of incentive type.
Caudate	Elliot et al. (2000)	Monetary gambling task, fMRI	9	Functional dissociation of gains and losses	Shows dissociable neural responses to rewards and penalties dependent on the experienced psychological context.
	Knutson et al. (2000a)	Monetary incentive delay task, fMRI	12	Functional dissociation of reward and punishment	Shows similar activation patterns in reward and punishment trials, but differences in a group analyses.
	Knutson et al. (2001a)	Monetary incentive task, fMRI	8	Functional dissociation of anticipation and outcome	Provides evidence that striatal areas code for expected incentive magnitude, a region in the nucleus accumbens codes for expected positive incentive value.

Region	Reference	Task	N	Focus	Findings
	Knutson et al. (2001b)	Monetary incentive delay task, fMRI	9	Functional dissociation of reward anticipation and outcome	Shows differential recruitment of regions along the trajectory of ascending dopamine projections in reward anticipation and outcomes.
	Spreckelmeyer et al. (2009)	Incentive delay task, fMRI	32	Men / women; monetary vs. social reward	Proposes that neural structures constituting the human reward system are proportionally activated for increasing levels of reward, independent of incentive type.
Cerebellar vermis	Knutson et al. (2001b)	Monetary incentive delay task, fMRI	9	Functional dissociation of reward anticipation and outcome	Shows differential recruitment of regions along the trajectory of ascending dopamine projections in reward anticipation and outcomes.
Cerebellum	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions.
Cingulate cortex	Elliot et al. (2000)	Monetary gambling task, fMRI	9	Functional dissociation of gains and losses	Shows dissociable neural responses to rewards and penalties dependent on the experienced psychological context.
	Knutson et al. (2000a)	Monetary incentive delay task, fMRI	12	Functional dissociation of reward and punishment	Shows similar activation patterns in reward and punishment trials, but differences in a group analyses.
	Knutson et al. (2001a)	Monetary incentive task, fMRI	8	Functional dissociation of anticipation and outcome	Provides evidence that striatal areas code for expected incentive magnitude, a region in the nucleus accumbens codes for expected positive incentive value.
	Kirsch et al. (2003)	Rewarded reaction time task, fMRI	27	Motivational value of money	Proposes that anticipation of a monetary reward produced stronger activation than the anticipation of positive verbal feedback due to motivation-dependent reactivity of the brain reward system.
	Knutson et al. (2003)	Monetary incentive delay task, fMRI	12	Functional dissociation of gains and losses	Suggests that in the context of processing monetary rewards, a region of the medial frontal cortex preferentially tracks rewarding outcomes.

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Region	Author	Task, Method		Topic	Findings
	Nieuwenhuis et al. (2005)	Monetary gambling task, fMRI	14	Range sensitivity	Shows that activity in the reward-sensitive brain areas is highly sensitive to the range of possible outcomes. Suggesting context-dependency of the brain's scaling of motivational value of events.
	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions.
Frontal cortex	Knutson et al. (2000a)	Monetary incentive delay task, fMRI	12	Functional dissociation of reward and punishment	Shows similar activation patterns in reward and punishment trials, but differences in a group analyses.
	Knutson et al. (2003)	Monetary incentive delay task, fMRI	12	Functional dissociation of gains and losses	Suggests that in the context of processing monetary rewards, a region of the medial frontal cortex preferentially tracks rewarding outcomes
	Hampton et al. (2006)	Decision-making task, fMRI	16	Monetary decision making	Suggests that key decision-making brain regions use an abstract model of task structure, based on higher-order structure rather simple reinforcement learning, to guide behavioral choice.
	Kim et al. (2006)	Instrumental choice task, fMRI	16	Avoidance learning, reinforcements	Shows that neural activity in the medial orbitofrontal cortex increased following the receipt of reward and the successful avoidance of an aversive outcome, thereby serving to reinforce actions during instrumental avoidance.
	Kable and Glimcher (2007)	Intertemporal choice task, fMRI	10	Monetary decision making, subjective choice	Suggests that the subjective value of potential rewards is explicitly represented in the human brain.
Frontal gyrus	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions.
	Becchio et al. (2011)	Judgment task, fMRI	20	Neuronal representation of the functional use of money.	Shows that destruction of money elicits activation within the same temporo-parietal network which is associated with the knowledge of the functional use of concrete tools.

Region	Reference	Task		Category	Description
Frontal pole	Knutson et al. (2001a)	Monetary incentive task, fMRI	8	Functional dissociation of anticipation and outcome	Provides evidence that striatal areas code for expected incentive magnitude, a region in the nucleus accumbens codes for expected positive incentive value.
Fusiform gyrus	Becchio et al. (2011)	Judgment task, fMRI	20	Neuronal representation of the functional use of money.	Shows that destruction of money elicits activation within the same temporo-parietal network, which is associated with the knowledge of the functional use of concrete tools.
Globus pallidus	Elliot et al. (2000)	Monetary gambling task, fMRI	9	Functional dissociation of gains and losses	Results revealed dissociable neural responses to rewards and penalties that were dependent on the psychological context in which they were experienced.
	Kirsch et al. (2003)	Rewarded reaction time task, fMRI	27	Motivational value of money	Proposes that anticipation of a monetary reward produced stronger activation than the anticipation of positive verbal feedback due to motivation-dependent reactivity of the brain reward system.
Hippocampus	Elliot et al. (2000)	Monetary gambling task, fMRI	9	Functional dissociation of gains and losses	Shows dissociable neural responses to rewards and penalties dependent on the experienced psychological context.
Hypothalamus	Breiter et al. (2001)	Gambling task, fMRI	12	Functional dissociation of experience and anticipation of rewards	Shows that responses to prospects and outcomes were generally, seen in the same regions. A common circuitry to the processing of diverse rewards is suggested.
Insula	Elliot et al. (2000)	Monetary gambling task, fMRI	9	Functional dissociation of gains and losses	Shows dissociable neural responses to rewards and penalties dependent on the experienced psychological context.
	Knutson et al. (2000a)	Monetary incentive delay task, fMRI	12	Functional dissociation of reward and punishment	Shows similar activation patterns in reward and punishment trials, but differences in a group analyses.
	Knutson et al. (2001b)	Monetary incentive delay task, fMRI	9	Functional dissociation of reward anticipation and outcome	Shows differential recruitment of regions along the trajectory of ascending dopamine projections in reward anticipation and outcomes.

	Reference	Task	N	Finding	Description
	Knutson et al. (2003)	Monetary incentive delay task, fMRI	12	Functional dissociation of gains and losses	Suggests that in the context of processing monetary rewards, a region of the medial frontal cortex preferentially tracks rewarding outcomes.
	Knutson et al. (2008)	Savings hold or purchase (SHOP) task, fMRI	24	Neural antecedents of the endowment effect	Shows greater nucleus accumbens activation for preferred products across buy and sell conditions combined, greater mesial prefrontal cortex activation in response to low prices (buying versus selling). Right insular activation for preferred products (selling) predicted individual differences in susceptibility to the endowment effect.
	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions.
Midbrain	Elliot et al. (2000)	Monetary gambling task, fMRI	9	Functional dissociation of gains and losses	Shows dissociable neural responses to rewards and penalties dependent on the experienced psychological context.
	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions
	Mobbs et al. (2009)	Reward-pursuit task, fMRI	14	Reduced performance for larger-than-average rewards	Shows that activation of the ventral midbrain correlates with reduced number of captures and increased number of near-misses associated with imminent high rewards relating to choking under pressure and "overmotivation."
Motor cortex	Knutson et al. (2001b)	Monetary incentive delay task, fMRI	9	Functional dissociation of reward anticipation and outcome	Shows differential recruitment of regions along the trajectory of ascending dopamine projections in reward anticipation and outcomes.
Nucleus accumbens	Knutson et al. (2000b)	Monetary incentive delay tasks, fMRI	12	Anticipation of increasing rewards	Demonstrates nucleus accumbens activity during reward anticipation indicating a key role in generating the experience of positive affect.

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Breiter et al. (2001)	Gambling task, fMRI	12	Functional dissociation of experience and anticipation of rewards	Shows that responses to prospects and outcomes were generally, seen in the same regions. A common circuitry to the processing of diverse rewards is suggested.
Knutson et al. (2001b)	Monetary incentive delay task, fMRI	9	Functional dissociation of reward anticipation and outcome	Shows differential recruitment of regions along the trajectory of ascending dopamine projections in reward anticipation and outcomes.
Kirsch et al. (2003)	Rewarded reaction time task, fMRI	27	Motivational value of money	Proposes that anticipation of a monetary reward produced stronger activation than the anticipation of positive verbal feedback due to motivation-dependent reactivity of the brain reward system.
Cooper and Knutson (2008)	Monetary incentive task, fMRI	12	Certain / uncertain outcomes; salience / valence	Suggests that in the nucleus accumbens different activation increases and decreases for gains and losses under outcome (un-) certainty, separately represent both valence and salience following appetitive motivation.
Knutson et al. (2008)	Savings hold or purchase (SHOP) task, fMRI	24	Neural antecedents of the endowment effect	Shows greater nucleus accumbens activation for preferred products across buy and sell conditions combined, greater medial prefrontal cortex activation in response to low prices (buying versus selling). Right insular activation for preferred products (selling) predicted individual differences in susceptibility to the endowment effect.
Spreckelmeyer et al. (2009)	Incentive delay task, fMRI	32	Men / women; monetary vs. social reward	Proposes that neural structures constituting the human reward system are proportionally activated for increasing levels of reward, independent of incentive type.
Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions.

Operculum

Region	Author (year)	Task, method	N	Title	Findings
Orbital gyrus	Breiter et al. (2001)	Gambling task, fMRI	12	Functional dissociation of experience and anticipation of rewards	Shows that responses to prospects and outcomes were generally, seen in the same regions. A common circuitry to the processing of diverse rewards is suggested.
Orbitofrontal cortex	O'Doherty et al. (2001)	Emotion-related visual reversal-learning task, fMRI	6	Functional dissociation of gains and losses	Shows that the magnitude of the brain activation correlated with the magnitude of the abstract rewards and punishments (gaining or losing money) received through emotional involvement.
	Elliott et al. (2003)	Rewarded target detection task, fMRI	12	Functional distinction of value and magnitude	Shows different response of brain regions to the reward's value suggesting functional distinction in response patterns within a distributed reward system.
	Kirsch et al. (2003)	Rewarded reaction time task, fMRI	27	Motivational value of money	Proposes that anticipation of a monetary reward produced stronger activation than the anticipation of positive verbal feedback due to motivation-dependent reactivity of the brain reward system.
	Plassmann et al. (2007)	Bidding task, fMRI	19	Willingness to pay, cognitive computation of financial resources	Provides evidence that activity in the medial orbitofrontal cortex and in the dorsolateral prefrontal cortex encodes subjects' willingness-to-pay suggesting that the medial orbitofrontal cortex encodes the value of goals in decision making.
	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Separate and common coding of monetary reward and punishment indistinct subregions of the cingulate cortex. However, the study does not support separate structures because same key regions were activated for both gains and losses.
Parietal cortex	Knutson et al. (2001a)	Monetary incentive task, fMRI	9	Functional dissociation of anticipation and outcome	Provides evidence that striatal areas code for expected incentive magnitude, a region in the nucleus accumbens codes for expected positive incentive value.

Region	Author (year)	Task, method	N	Topic	Finding
	Knutson et al. (2003)	Monetary incentive delay task, fMRI	12	Functional dissociation of gains and losses	Suggests that in the context of processing monetary rewards, a region of the medial frontal cortex preferentially tracks rewarding outcomes.
	Nieuwenhuis et al. (2005)	Monetary gambling task, fMRI	14	Range sensitivity	Shows that activity in the reward-sensitive brain areas is highly sensitive to the range of possible outcomes. Suggesting context-dependency of the brain's scaling of motivational value of events.
Parietal lobule	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions.
Precentral gyrus	Becchio et al. (2011)	Judgment task, fMRI	20	Neuronal representation of the functional use of money.	Shows that destruction of money elicits activation within the same temporo-parietal network, which is associated with the knowledge of the functional use of concrete tools.
Precuneus	Spreckelmeyer et al. (2009)	Incentive delay task, fMRI	32	Men / women; monetary vs. social reward	Proposes that neural structures constituting the human reward system are proportionally activated for increasing levels of reward, independent of incentive type.
	Becchio et al. (2011)	Judgment task, fMRI	20	Neuronal representation of the functional use of money.	Shows that destruction of money elicits activation within the same temporo-parietal network, which is associated with the knowledge of the functional use of concrete tools.
Prefrontal cortex	Elliot et al. (2000)	Monetary gambling task, fMRI	9	Functional dissociation of gains and losses	Shows dissociable neural responses to rewards and penalties dependent on the experienced psychological context.
	Knutson et al. (2001a)	Monetary incentive task, fMRI	8	Functional dissociation of anticipation and outcome	Provides evidence that striatal areas code for expected incentive magnitude, a region in the nucleus accumbens codes for expected positive incentive value.
	Nieuwenhuis et al. (2005)	Monetary gambling task, fMRI	14	Range sensitivity	Shows that activity in the reward-sensitive brain areas is highly sensitive to the range of possible outcomes. Suggesting context-dependency of the brain's scaling of motivational value of events.

Region	Author (Year)	Task, Method	N	Title	Description
	Daw et al. (2006)	Gambling task, fMRI	14	Exploration-exploitation-dilemma	Proposes that different brain regions are active during exploratory and exploitative decision making suggesting action selection under uncertainty that involves switching between exploratory and exploitative behavioral modes.
	Knutson et al. (2008)	Savings hold or purchase (SHOP) task, fMRI	24	Neural antecedents of the endowment effect	Shows greater nucleus accumbens activation for preferred products across buy and sell conditions combined, greater mesial prefrontal cortex activation in response to low prices (buying versus selling). Right insular activation for preferred products (selling) predicted individual differences in susceptibility to the endowment effect.
	Hampton et al. (2006)	Decision-making task, fMRI	16	Higher-order decision making	Suggests that key decision-making brain regions use an abstract model of task structure, based on higher-order structure rather simple reinforcement learning, to guide behavioral choice.
	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions.
	Weber et al. (2009)	Estimation task, fMRI	24	Money illusion	Proposes that ventromedial prefrontal cortex exhibited money illusion.
Premotor cortex	Elliott et al. (2003)	Rewarded target detection task, fMRI	12	Functional distinction of value and magnitude	Shows different response of brain regions to the reward's value suggesting functional distinction in response patterns within a distributed reward system.
Putamen	Knutson et al. (2000a)	Monetary incentive delay task, fMRI	12	Functional dissociation of reward and punishment	Shows similar activation patterns in reward and punishment trials, but differences in a group analyses.
	Knutson et al. (2001b)	Monetary incentive delay task, fMRI	9	Functional dissociation of reward anticipation and outcome	Shows differential recruitment of regions along the trajectory of ascending dopamine projections in reward anticipation and outcomes...

	Study	Task	N	Topic	Description
	Kirsch et al. (2003)	Rewarded reaction time task, fMRI	27	Motivational value of money	Proposes that anticipation of a monetary reward produced stronger activation than the anticipation of positive verbal feedback due to motivation-dependent reactivity of the brain reward system.
Striatum	Delgado et al. (2000)	Monetary gambling task	9	Functional dissociation of gains and losses	Shows that activation in different brain regions was sustained following a reward feedback, but decreased below baseline following a punishment feedback.
	Elliot et al. (2000)	Monetary gambling task, fMRI	9	Functional dissociation of gains and losses	Shows dissociable neural responses to rewards and penalties dependent on the experienced psychological context.
	Elliott et al. (2003)	Rewarded target detection task, fMRI	12	Functional distinction of value and magnitude	Shows different response of brain regions to the reward's value suggesting functional distinction in response patterns within a distributed reward system.
	Knutson et al. (2003)	Monetary incentive delay task, fMRI	12	Functional dissociation of gains and losses	Suggests that in the context of processing monetary rewards, a region of the medial frontal cortex preferentially tracks rewarding outcomes
	Nieuwenhuis et al. (2005)	Monetary gambling task, fMRI	14	Range sensitivity, value and magnitude	Shows that activity in the reward-sensitive brain areas is highly sensitive to the range of possible outcomes. Suggesting context-dependency of the brain's scaling of motivational value of events.
	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions.
Temporal gyrus	Fujiwara et al. (2009)	Free-choice task, fMRI	17	Cingulate activations for different levels of monetary gain and loss	Provides evidence for separate and common coding, but not separate structures, of monetary reward and punishment in distinct brain regions
Thalamus	Elliot et al. (2000)	Monetary gambling task, fMRI	9	Functional dissociation of gains and losses	Results revealed dissociable neural responses to rewards and penalties that are dependent on the psychological context in which they are experienced.

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Study	Task, Method	N	Topic	Finding
Knutson et al. (2000a)	Monetary incentive delay task, fMRI	12	Functional dissociation of reward and punishment	Shows similar activation patterns in reward and punishment trials, but differences in a group analyses.
Knutson et al. (2001b)	Monetary incentive delay task, fMRI	9	Functional dissociation of reward anticipation and outcome	Shows differential recruitment of regions along the trajectory of ascending dopamine projections in reward anticipation and outcomes.
Kirsch et al. (2003)	Rewarded reaction time task, fMRI	27	Motivational value of money	Proposes that anticipation of a monetary reward produced stronger activation than the anticipation of positive verbal feedback due to motivation-dependent reactivity of the brain reward system.
Knutson et al. (2003)	Monetary incentive delay task, fMRI	12	Functional dissociation of gains and losses	Suggests that in the context of processing monetary rewards, a region of the medial frontal cortex preferentially tracks rewarding outcomes
Spreckelmeyer et al. (2009)	Incentive delay task, fMRI	32	Men / women; monetary vs. social reward	Proposes that neural structures constituting the human reward system are proportionally activated for increasing levels of reward, independent of incentive type.

Note. Studies were sorted alphabetically by brain area and then chronologically within each brain area.

Table 3

Activation changes for time compared to money during the "priming phase"

Brain area	Hemi-sphere	Brodmann area	x	y	z	t(42)	p
Insula	Right	13	44	-26	15	3.96	.0003
Insula	Left	13	-31	-23	18	4.18	.0001
Medial temporal gyrus	Left	21	-67	-44	0	3.88	.0004

Note. $N = 43$; random-effects general linear model. Brain areas, Brodmann areas, and Talairach coordinates (Talairach and Tournoux, 1988) refer to the peak activation voxel within each cluster of continuous voxels at a global threshold of $p < .01$ (uncorrected) and a minimum cluster threshold of seven voxel to ensure a total maximum false activation rate of .05.