7 Brain, Decision, and Debt*

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Overview

In this chapter, we summarize recent findings in neuroeconomics suggesting that emotion (specifically, "anticipatory affect") can influence financial decisions, and then discuss how individual differences in anticipatory affect may promote proneness to consumer debt. Thanks to improvements in spatial and temporal resolution, functional magnetic resonance imaging (FMRI) experiments have begun to suggest that activation of a brain region associated with anticipating gains (i.e., the nucleus accumbens or NAcc) precedes an increased tendency to seek financial gains, whereas activation of another region associated with anticipating losses (i.e., the anterior

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insula) precedes an increased tendency to avoid financial losses. By extension, individual differences in increased gain anticipation, decreased loss anticipation, or some combination of the two (plus a third nonreflective factor) might promote proneness to debt (Knutson, Samanez-Larkin, and Kuhnen 2011). Ultimately, neuroeconomic advances may help individuals to optimize their investment strategies, as well as empower institutions to minimize consumer debt.

Neuroeconomists seek to explain how brains choose. Thanks to technological advances, scientists can now "open the black box" of the brain, moving below the surface mapping between input and output to identification of mediating neural and psychological processes. Thus, neuroeconomic methods might allow scientists to bridge gaps between neural, psychological, and behavioral levels of analysis. Below, we summarize ongoing attempts to forge links from affective neural circuits to affective experience and, eventually, to decisions that can lead to debt.

Defining Debt and Potential Causes

To study whether individual difference variables influence life financial outcomes, one must first measure financial outcomes. Based on standard accounting practices, life financial outcomes might broadly be divided into two classes: assets (related to savings) and debt (related to outstanding expenditures). Although assets and debt undoubtedly fluctuate over time in response to significant life events and the general economic climate, they may also show some temporal stability both within and across individuals. We focus on debt below, operationally defined as money owed to any lender over an extended period of time—although finer-grained analyses might distinguish home ownership (i.e., mortgage) debt from other types of debts (e.g., revolving credit card debt). Even given such a rough index, continuous measures of debt might allow investigators to determine whether and which individual difference factors promote debt. Eventually, measures of debt should ideally demonstrate both test-retest reliability (e.g., similarity across instances of measurement) and validity (e.g., self-report should agree with credit reports) (Knutson et al. 2011).

Research has repeatedly linked both situational and personal factors to debt (Lea, Webley, and Levine 1993; Stone and Maury 2006). Economically, young people, people with lower incomes, or people who have suffered recent financial hardship are more likely to be in debt. Psychologically, more permissive attitudes toward debt and perceived control over finances have been linked to debt in some, but not all, studies. Beyond these factors, over a century of research suggests that individuals reliably differ in terms of intelligence and socio-emotional capacities, and that these traits have a substantial heritable component (> 50 percent of variation across individuals) (McGue and Bouchard 1998). Few studies, however, have examined the direct influence of these factors on debt proneness. This gap in the literature may partially result from the fact that primarily psychologists study individual differences in cognitive and emotional function, whereas primarily economists focus on life financial outcomes such as debt (for exceptions, see Knutson et al. 2011; Lea, Mewse, and Wrapson 2012: ch. 6).

Indebtedness implies one or more earlier decisions to take on debt. From a psychological standpoint, the decision to take on debt involves choosing present gain at the cost of a greater future loss. The decision to take on debt thus involves two classes of decisions that have proven most difficult to explain with rational choice models. First, taking on debt involves weighing potential gains versus losses and, thus, may be related to risk preference. Second, taking on debt also involves weighing potential present gains versus future losses, and so may be related to time preference. In cases of both risk preference and time preference, theorists have sought to account for anomalies in choice (e.g., inconsistency) by invoking emotional mechanisms (Ainslie 1992; Loewenstein, Weber, Hsee, and Welch 2001). If emotion influences immediate choices, and does so repeatedly and consistently over time, it might have a significant cumulative impact on life financial outcomes such as debt.

The Anticipatory Affect Model

Although evolutionary theorists have accorded emotion a central role in ancestral choices related to survival and procreation (e.g., approaching sexual opportunities or avoiding predatory threats) (Darwin 1872), the importance of emotion in choices related to abstract incentives (e.g., money) is less clear. In fact, a rational actor might well rely solely upon abstract numerical representations to make optimal financial choices. Accumulating brain imaging research, however, suggests that even complex financial choices recruit evolutionarily preserved neural circuits implicated in emotion (Knutson and Greer 2008).

Although popular sentiment implies that emotions can influence choice, physiological evidence for such an influence has remained elusive. Part of the difficulty in studying the influence of emotions on decisions has to do with emotion's dynamic and transient nature. Researchers have traditionally focused on affective reactions to events only after they occur—"consequential" affect (Loewenstein, Weber, Hsee, and Welch 2001). For instance, researchers might measure the affect elicited by unexpected positive versus negative events, or by success versus failure in achieving goals (Carver and White 1994; Isen, Nygren, and Ashby 1988). Although more recent affective forecasting models have focused on predicted affective responses to events (Wilson and Gilbert 2003), these affective forecasting models are still "consequentialist" because they refer to peoples' predictions about their affective responses to outcomes rather than how people will feel during anticipation of those outcomes. Affect that occurs during anticipation ("anticipatory" affect), however, is best situated in time to influence upcoming decisions.

Accordingly, we have proposed an "anticipatory affect model" in which anticipation of significant outcomes alters both affective arousal and valence (Knutson and Greer 2008; Wundt 1897). The model assumes that all future outcomes are subjectively uncertain (i.e., probability < 1 and > 0), and all uncertain outcomes potentially evoke anticipation of both gains and losses. The anticipation elicited by incentive cues resolves when uncertainty collapses as the outcome either occurs or does not. During anticipation, uncertainty increases arousal, whereas potential gains increase valence and potential losses decrease valence. Thus, anticipation of uncertain gains should increase positive arousal (e.g., feelings such as excitement), whereas anticipation of uncertain losses should increase negative arousal (e.g., feelings such as anxiety), which are psychometrically defined as independent rather than opposite affective states (Watson and Tellegen 1985).

In addition to generating affective experience, positive arousal should promote approach behavior, whereas negative arousal should promote avoidance behavior. The anticipatory affect model can thus forecast the effect of incentive cues on risk taking. Specifically, positive incentive cues should elicit nucleus accumbens (NAcc) activation and positive arousal, which should facilitate risk taking, whereas negative incentive cues should elicit anterior insular activation and negative arousal, which should diminish risk taking (Figure 7.1).

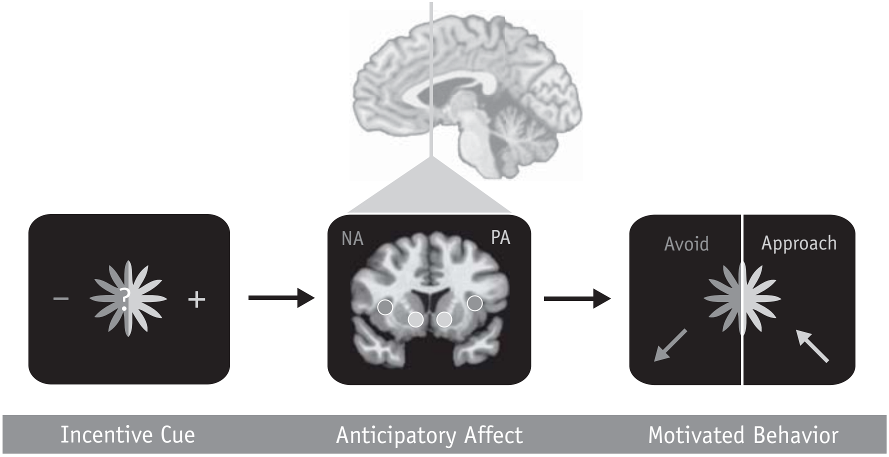

FIGURE 7.1 Anticipatory affect model (adapted from Knutson and Greer 2008).

By extending prior accounts that focused primarily on arousal but not valence during anticipation (Loewenstein Weber, Hsee, and Welch 2001), the anticipatory affect model generates a number of novel predictions about how emotion might influence subsequent financial choices (Knutson and Greer 2008). First, neural circuits that generate positive arousal and negative arousal should both show increased activation during anticipation of uncertain outcomes, but differential activation in response to anticipated gain versus loss. Second, significant activation of these circuits should correlate with the self-reported experience of positive arousal and negative arousal, respectively. Third, significant activation of these circuits should have consequences for an immediately subsequent choice. As elaborated below, emerging neural evidence broadly supports these predictions for immediate choices.

By temporal extension, the anticipatory affect model also might yield predictions about life financial outcomes. To promote the decision to take on debt, the promise of immediate monetary gain might elicit increased positive arousal, the promise of delayed monetary loss might not elicit sufficient negative arousal, or some combination of the two. Researchers are just beginning to turn their attention toward these implications for distant or cumulative choices.

Neural Circuits for Anticipatory Affect

Which brain regions might index anticipatory affect in humans? Animal research provides some leads (Panksepp 1998). Electrical stimulation of mesolimbic circuitry elicits approach behavior in all mammalian species studied (Olds and Fobes 1981). The mesolimbic circuit receives dopamine projections from midbrain neurons (in the ventral tegmental area) and includes both subcortical (i.e., the lateral hypothalamus and the ventral striatum including the NAcc) and cortical (i.e., the medial prefrontal cortex or MPFC) components. Further, anatomical studies of both monkeys and humans indicate that striatal and prefrontal cortical regions interconnect in an “ascending spiral” fashion, running from lower regions implicated in motivation to higher regions implicated in movement (Draganski, Klöppel, Cook, Alexander, Parker, Deichmann, Ashburner, and Frackowiak 2008; Haber, Fudge, and McFarland 2000; Lehéricy, Ducros, Van de Moortele, Francois, Thivard, Poupon, Swindale, Ugurbil, and Kim 2004). Thus, stimulation and connectivity literatures converge to implicate NAcc (and interconnected MPFC) activation as a promising potential neural marker for positive arousal (Figure 7.1, lighter gray circles).

The connections of circuitry in which electrical stimulation elicits avoidance behavior—descending from the insula (Figure 7.1, darker gray circles) and amygdala to the medial hypothalamus and periaqueductal grey of the brainstem—have received less attention in the literature. In this circuit, the anterior insula lies closest to and shares prominent connections with the prefrontal cortex, particularly with the lateral prefrontal cortex, but also with the MPFC (Mesulam and Mufson 1985). Thus, the anterior insula (and interconnected amygdala) might provide candidates for neural markers of negative arousal. The distinctness of these regions not only implies that positive arousal and negative arousal are subserved by distinct circuits, but also that the output of these circuits may converge in the MPFC (and the interconnected medial caudate) to influence behavior.

The first prediction of the anticipatory affect model that anticipation of gain and anticipation of loss recruit activation in distinct neural circuits can be addressed with a judicious combination of brain imaging and incentive tasks. The development of FMRI in the early 1990s provided the necessary spatial and temporal resolution (in millimeters and seconds) to allow researchers to visualize transient changes in activation of these subcortical structures in behaving humans. Initial studies (around year 2000) manipulated anticipation of gains and losses in the absence of choice (usually in the context of delayed response or gambling tasks). More recent studies included choice and used brain activation from previously identified regions to predict choice. In both types of studies, monetary incentives provided a powerful experimental tool, because experimenters could control anticipation versus outcome, gain versus loss, magnitude, probability, and other aspects of anticipation (Knutson and Cooper 2005).

A prototypical example of a task that elicits anticipation of gain and anticipation of loss is called the "monetary incentive delay" (MID) task (Knutson, Westdorp, Kaiser, and Hommer 2000). The MID task's design was inspired by the historic observation that in addition to food taste, food cues can elicit salivation in dogs (Pavlov 1927). More recent electrophysiological evidence similarly suggests that juice cues elicit increased firing of dopamine neurons in monkeys (Schultz 1998). In a typical MID task trial, subjects initially see a cue indicating that they will have an opportunity to either gain or avoid losing a certain amount of money, followed by a fixation cross. Next, a target briefly appears on the screen, and subjects attempt to press a button before the target is replaced by a fixation cross. Finally, subjects see the outcome of their performance on that trial as well as their cumulative earnings.

The structure of the MID task allows separate visualization of brain responses during anticipation of incentives and their outcomes. Separation of gain and loss trials enables investigators to directly compare neural responses to gains versus losses and to control for potential confounds (related to sensory input, motor output, arousal or salience, and performance). Initial findings suggested that anticipation of monetary gain proportionally increased NAcc activation (Knutson Adams, Fong, and Hommer 2001). In contrast, gain versus nongain outcomes increased activation in a part of the MPFC and the posterior cingulate, after controlling for anticipation (Knutson, Fong, Bennett, Adams, and Hommer 2003). A recent meta-analysis of a decade of these types of studies verified the strength and reproducibility of this pattern of findings (Knutson and Greer 2008). As in initial reports, gain anticipation elicits greater activation in the NAcc, whereas loss anticipation elicits greater activation in some (but not all) regions of the anterior insula. Together, these findings are consistent with the prediction that anticipation of gain and anticipation of loss recruit distinct neural circuits.

The second prediction of the anticipatory affect model can be assessed by correlating brain activation with self-reported affective experience (assessed either retrospectively or online). In the MID task, anticipation of gains increases positive arousal, whereas anticipation of losses increases negative arousal. Further, anticipatory affect increases proportional to the magnitude of anticipated gain or loss (Samanez-Larkin, Gibbs, Khanna, Nielsen, Carstensen, and Knutson 2007) (Figure 7.2). Peripheral indices of arousal (e.g., skin conductance) also increase when subjects anticipate gains and losses (Nielsen, Knutson, Kaufman, Weinstein, and Carstensen 2004). These findings suggest that in addition to altering brain activation, anticipation of incentives reliably changes self-reported affective experience within subjects.

Although anticipation of incentives influences affect, do individual differences in neural responses correlate with individual differences in affective response? Studies that explored this association found that NAcc activation correlates with gain-cue-elicited positive arousal but not negative arousal (Bjork, Knutson, Fong, Caggiano, Bennett, and Hommer 2004; Knutson, Adams, Fong, and Hommer 2001; Knutson, Taylor, Kaufman, Peterson, and Glover 2005). The specificity of insular activation to negative arousal, however, is less clear. For instance, one study

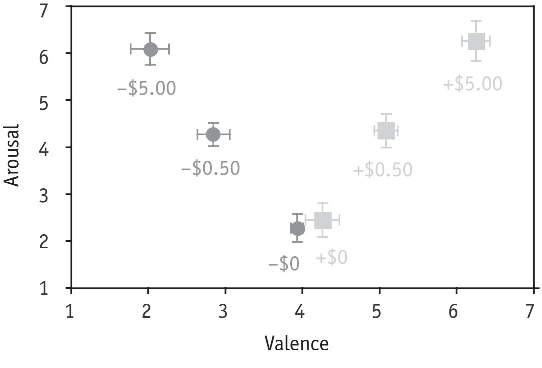

FIGURE 7.2 Changes in affect during anticipation of monetary gains and losses relative to nonmonetary outcomes (adapted from Samanez-Larkin, Gibbs, Khanna, Nielsen, Carstensen, and Knutson 2007). For valence scale on x-axis 1 = very negative, 4 = neutral, 7 = very positive. For arousal scale on y-axis 1 = not at all aroused, 7 = very aroused.

found that insular activation during anticipation of losses correlated with both negative arousal and positive arousal (Samanez-Larkin, Gibbs, Khanna, Nielsen, Carstensen, and Knutson 2007). These findings mostly support the prediction that neural activity should correlate with affective experience during anticipation. Although most peripheral physiological measures (e.g., skin conductance, pupillary dilation) index arousal, current findings suggest that brain activity (especially in the NAcc) also indexes valence, which should provide critical information for predicting choice.

To test the third prediction of the anticipatory affect model that brain activation can predict choice, investigators must reverse the traditional logic of brain imaging studies. Instead of examining the effects of input (e.g., cues) on neural responses, investigators focus on whether neural activation predicts subsequent output (e.g., the choice to approach or avoid). This additional constraint potentially focuses predictions, because anticipation of incentives may activate many regions, but only a subset of those regions might influence upcoming choice. Investigators have used brain activation to predict choice in the context of financial decisions that include purchasing and investment.

With respect to purchasing, an initial FMRI study investigated subjects' neural responses to products and associated prices before choosing whether or not to purchase. Findings indicated that although NAcc activation increased when subjects viewed preferred products, right anterior insula activation increased when subjects viewed excessive prices (i.e., the displayed price was higher than subjects were willing to pay). Importantly, NAcc activation during product presentation predicted that subjects would be more likely to buy a product, whereas insula activation during price presentation predicted that subjects would be less likely to buy a product (Knutson, Rick, Wimmer, Prelec, and Loewenstein 2007). After entering only the brain activation variables into a logistic regression, trial-to-trial purchases could be predicted at approximately 60 percent (versus 50 percent chance, confirmed by cross-validation). New analytic techniques that can account for multivariate correlations, moreover, increase this prediction rate to 67 percent (Grosenick, Greer, and Knutson 2008), and continuing statistical refinements that incorporate information from the whole brain may increase the prediction rate further.

Other studies have used brain activation to predict choice in the context of investing. For instance, the first FMRI study to use brain activity to predict choice on a trial-to-trial basis did so during an investing task (Kuhnen and Knutson 2005). Although earlier studies had associated NAcc activation with risk seeking and anterior insula activation with risk aversion, they lacked the temporal resolution to establish whether correlated activation had occurred before or after choice (Matthews, Simmons, Lane, and Paulus 2004; Paulus, Rogalsky, Simmons, Feinstein, and Stein

2003). In a study designed to mimic financial investing, investigators examined subjects' anticipatory activation before they made high-risk (stock) or low-risk (bond) investment choices. Further, the investigators determined whether subjects' choices matched those of a risk-neutral rational (Bayesian updating) actor. After controlling for econometric variables (uncertainty, overall wealth, previous actual earnings, and previous counterfactual earnings), findings indicated that anticipatory NAcc activation preceded both optimal and suboptimal risk-seeking (stock) choices, whereas anticipatory anterior insula activation preceded both optimal and suboptimal risk-averse (bond) choices. These effects were most prominent before investors switched choice strategies, implicating these brain circuits to a greater extent in choices involving uncertainty than in habitual responses. Additionally, subjects with greater insula activation overall tended to make more risk-averse choices (Kuhnen and Knutson 2005).

Together, these findings support key implications of the anticipatory affect model—anticipation of incentives elicits brain activation, which correlates with anticipatory affect, and can be used to predict choice. Although consistent with a causal story, however, this evidence is correlational. One could test the causal effect of activation in these circuits on financial choice by increasing their activity prior to choice opportunities. Moreover, such an intervention need not necessitate electrodes and invasive surgery, because incidental affective stimuli can also increase activation in some of these circuits. Indeed, presentation of erotic pictures (versus frightening or neutral pictures) to heterosexual males increases their tendency to take financial risks, and this behavioral effect is partially mediated by increases in NAcc activation (Knutson, Wimmer, Kuhnen, and Winkielman 2008).

Although the above findings focus on immediately upcoming choice, emerging evidence is beginning to suggest that individual differences in NAcc function might bias people toward gain seeking, whereas individual differences in insula function might bias people toward loss avoidance. For instance, in the investment task described above, when individuals' NAcc activation matched the expected value of available risky choices, they tended to make more rational risk-seeking choices (Samanez-Larkin, Wagner, and Knutson 2011). Additionally, these individuals reported greater real-life assets on average (Samanez-Larkin, Kuhnen, Yoo, and Knutson 2010). In another study, differences in insular activity during loss anticipation predicted individuals' abilities to learn to avoid monetary loss in a separate task months after scanning (Samanez-Larkin, Hollon, Carstensen, and Knutson 2008) (Figure 7.3). In a recent study extending these findings to life financial outcomes, we found that individuals who learned more rapidly to seek monetary gains had more financial assets, whereas those who learned more rapidly to avoid monetary losses had less financial debt in the real world (Knutson et al. 2011). Based on these

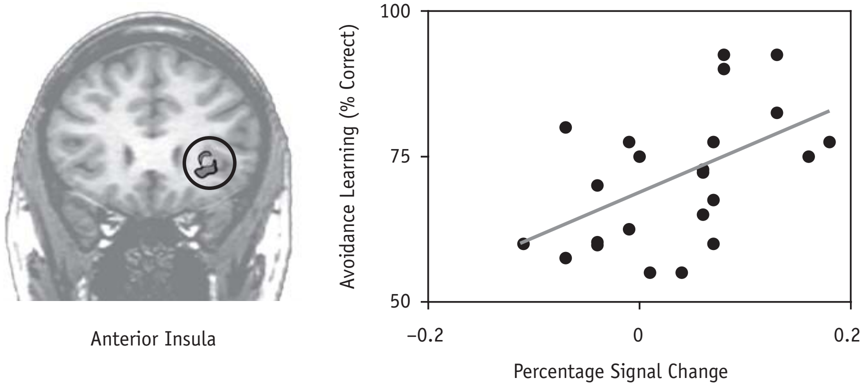

FIGURE 7.3 Right insular activation during loss anticipation predicts ability to avoid loss months later (adapted from Samanez-Larkin, Hollon, Carstensen, and Knutson 2008).

findings, an obvious direction for future research involves assessing neural and behavioral responses to incentives and correlating these with real-life financial outcomes, including debt.

Overall, brain activity associated with anticipatory affect can be used to predict surprisingly diverse financial choices. Specifically, although NAcc activation predicts approaching gains (e.g., purchasing desirable products and approaching risky investments), anterior insular activation predicts avoidance of losses (e.g., not purchasing overpriced products and avoiding risky investments). Stimuli or events that incidentally increase activation in these regions can also alter immediately subsequent financial choices. Although we have focused here on findings from our laboratory (Knutson and Cooper 2005), many others have reported corroborating evidence (O'Doherty 2004). For instance, activation in the NAcc plays a key role in learning to seek monetary gains, whereas activation in the insula plays a key role in learning to avoid monetary losses (Pessiglione, Seymour, Flandin, Dolan, and Frith 2006).

Conclusions and Implications

Improvements in brain imaging technology are revealing a new view of human financial choice. This new view goes below the cortex, changes dynamically on a second-to-second basis, and implicates evolutionarily ancient circuits associated with affect alongside more recently evolved circuits associated with deliberation. Emerging findings suggest that incentive cues activate distinct circuits, that this activation correlates with affective experience, and that it can be used to predict subsequent choices. Specifically, NAcc activation precedes approach toward potential gains, whereas anterior insula activation precedes avoidance of potential losses. Additional findings (not reviewed here) suggest that prefrontal regions may integrate these gain and loss evaluations and allow people to project themselves into the future, facilitating integration of more abstract properties of incentives (e.g., probability and delay). Together, these results have begun to support a nascent model of the influence of anticipatory affect on financial and other choices.

Although remarkable progress has occurred in the decade-and-a-half since FMRI's inception, the current literature only provides a handful of preliminary demonstrations. Technically, brain imaging hardware and software improve each year, but neither has yet been fully optimized for utilizing brain activity to predict choice. Conceptually, existing studies have been able to use brain activation to predict immediate choice, yet the same frameworks could be extended to prediction of distal choices, as well as to the detection of chronic biases that might cumulate and alter life financial outcomes. Some of the existing evidence already elucidates phenomena relevant to debt. For instance, individual differences in anterior insula activation can account for differential risk aversion in an investment task (Kuhnen and Knutson 2005), and individual differences in anterior insula activation in a cued response task can account for differential loss avoidance in a separate laboratory task (Samanez-Larkin, Hollon, Carstensen, and Knutson 2008). These and related clinical findings (Paulus and Stein 2006) suggest that increased insular sensitivity may bias individuals toward avoiding loss in general, which may extend to the specific realm of finance. If financial laboratory tasks generalize to real-world outcomes, individuals who are sensitive to loss anticipation may repeatedly avoid debt. Current research in our laboratory is examining this prediction, using both self-report and more objective measures of debt.

Neuroeconomic studies thus enable investigators to decompose apparently unitary phenomena (such as choice) into subcomponents (such as anticipatory affect). Successful decomposition might imply targeted applications. For instance, if a lack of sensitivity to future loss plays a more powerful role in promoting debt than the attractiveness of present gains, then personal interventions for reducing debt might involve creative ways of making the loss obvious and bringing it into the present, or other means of recruiting the anterior insula. Beyond enhancing personal control, institutions might use such neuroeconomic findings to implement wise choice architecture or craft policy (as in the case of setting organ donation as the applicable default rule so that people need not confront an unpleasant decision) (Johnson and Goldstein 2003; Thaler and Sunstein 2008).

Of course, mechanistic knowledge of the underpinnings of choice could be used for nefarious as well as benevolent purposes. Theorists have argued that some institutions actively encourage debt, ranging from credit cards (which substitute and defer costs) to credit default swaps (which disperse and hide risk) (Prelec and Loewenstein 1998). These institutions probably evolved to achieve desired effects, however, rather than from any deep understanding of the neuropsychological mechanisms that support choice. Thus, individuals may derive greater benefit from an explicit understanding of these mechanisms, because understanding rather than ignorance will more likely confer control.

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