Modeling the Interplay Between Affect and Deliberation

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Drawing on diverse lines of research in psychology, economics, and neuroscience, we develop a model in which a person's behavior is determined by an interaction between *deliberative processes* that assess options with a broad, goal-based perspective, and *affective processes* that encompass emotions and other motivational states. Our model provides a framework for understanding many departures from rationality discussed in the literature and captures the familiar feeling of being "of 2 minds." Most important, by focusing on factors that moderate the relative influence of the 2 processes, our model generates a variety of novel testable predictions. We apply our model to intertemporal choice, risky decisions, and social preferences.

Keywords: decision making, dual process, dual system, willpower, intertemporal choice, risk, social preferences

From the writings of the earliest philosophers to the present, there has been an almost unbroken belief that human behavior is best understood as the product of two interacting and often competing processes. Many recent dual process perspectives have focused on the differences between two different modes of thinking—for

example, controlled versus automatic processes (Shiffrin & Schneider, 1977), symbolic and associative processes (Sloman, 1996; Smith & DeCoster, 2000), impulsive and reflective processes (Lieberman, 2003; Strack & Deutsch, 2004), and System I and II (Kahneman & Frederick, 2002). In this article, we also propose a dual-process framework; however, our focus is on choice behavior rather than judgment. Following a long tradition of perspectives drawing a distinction between, for example, "passion versus reason," "the id and the ego," and more recently, "emotion and cognition," we argue that choice behavior can be seen as the product of two motivational processes, one more deliberative and focused on broader goals and the other more reflexive and driven by emotions and other motivational states.

Although both affect and deliberation have been the focus of considerable research, when it comes to formal modeling, one process—the more deliberative of the two—has received the lion's share of attention. Considerable intellectual time and energy has gone into formulating what are sometimes referred to as cognitive or rational-choice models of decision making, such as the expected-utility model and the discounted-utility model. Such models are consequentialist in character; they assume that people

choose between different courses of action based on the desirability of their consequences. Attempts to increase the realism of such models, many associated with the field of behavioral decision research, have generally adhered to the consequentialist perspective but modify assumptions about probability weighting, time discounting, or the specific form of the utility function.

A major reason for this focus is that the other process—affect—has long been viewed as erratic and unpredictable, and hence too complicated to incorporate into formal models. In recent years, however, there has been a renewed interest in emotion, which has revealed a number of systematic properties of both the determinants and consequences of affect. New research by social psychologists (Epstein, 1994; Sloman, 1996; Wilson et al., 2000), neuroscientists (Damasio, 1994; LeDoux, 1996; Panksepp, 1998; Rolls, 1999) and decision researchers (Lerner & Keltner, 2000, 2001; Loewenstein, 1996; Loewenstein et al., 2001; Mellers et al., 1997; Peters & Slovic, 2000; Pham, 1998; Slovic et al., 2002) has led to a better understanding of the role that affect plays in decision making, much of it lending new support to historical dual-process views of human behavior. As of yet, however, there have been few attempts to develop formal models of behavior that incorporate these insights, and in particular to address how affect and deliberation interact to determine human behavior.

We propose a formal dual-process model in which a person's behavior is the joint product of a *deliberative system* that assesses options in a consequentialist fashion and an *affective system* that encompasses emotions such as anger and fear and motivational states such as hunger, sex, and pain. The model provides a new conceptual framework for understanding many of the documented departures from the standard rational-choice model discussed in behavioral decision research, behavioral economics, and judgment and decision making research. At the same time, it captures the familiar feeling of being "of two minds"—of simultaneously thinking one should behave one way while actually behaving in a different way (see, e.g., Milkman et al., 2008). Most important, by focusing on factors that moderate the relative influence of the two processes, the model generates a number of novel testable predictions.

A Dual-Process Model of Behavior

In psychology, the dual-process models that are closest in spirit to our own are Metcalfe and Mischel's hot/cool model (1999) and Fazio and Towles-Schwen's (1999) MODE model. Metcalfe and Mischel (1999) distinguish between a "hot emotional system" and a "cool cognitive system" and assume that a person's behavior depends on which system is dominant at a particular moment. Fazio and Towles-Schwen's (1999) MODE model similarly distinguishes two types of attitude-to-behavior processes, spontaneous processing and deliberative processing, with implicit, automatically activated attitudes guiding spontaneous processing, and explicit attitudes guiding deliberative processing.

Economists, too, have developed dual-process models of human behavior along these lines (Benhabib & Bisin, 2005; Bernheim & Rangel, 2004; Fudenberg & Levine, 2006; Shefrin & Thaler, 1988; Thaler & Shefrin, 1981; and an earlier version of the current article, Loewenstein & O'Donoghue, 2004). While our model overlaps with these models in ways we will discuss, all of these models (except the one on which the current model is based) focus exclusively on intertemporal choice. In this article, we apply our model to a variety of decision-making domains, including intertemporal choice, in which some of our assumptions—particularly affective myopia—overlap with those made by these other economic approaches.

Our model is also informed and motivated by evidence from neuroscience on the functional specificity of different regions of the human brain. Evolutionarily older brain regions, such as the limbic system, which includes areas such as the amygdala and the hypothalamus, evolved to promote survival and reproduction, incorporate affective mechanisms (MacLean, 1990). In contrast, the seemingly unique human ability to choose deliberately, by focusing on broader goals, relies on the prefrontal cortex (Damasio, 1994; Lhermitte, 1986; Miller & Cohen, 2001), the region of the brain that expanded most dramatically in the course of human evolution (Manuck et al., 2003). Indeed, these results have led to dual-system frameworks for the neuroscience of decision making. These focus on the distinction between valuation-based choices and goal-directed choices, with the former being processed primarily in areas such as the

amygdala and the ventromedial prefrontal cortex, and the latter being processed primarily in areas such as the dorsolateral prefrontal cortex (Daw, Niv, & Dayan, 2005; Hare, O'Doherty, Camerer, Schultz, & Rangel, 2008; see also Bechara, Damasio, Tranel, & Damasio, 1997 for an alternate but complementary approach to studying the role of emotions in decision making). Of course, there are many important distinctions between different dual-process accounts, and both the functional and neurobiological properties of these different systems are still up for debate (see, e.g., Kable & Glimcher, 2009).[1]

Our use of the term affect differs from many lay definitions, which tend to focus on the subjective feeling states associated with emotions. In our usage, the defining characteristic is that affects carry "action tendencies" (Frijda, 1986)—for example, anger motivates us to aggress, pain to take steps to ease the pain, and fear to escape (or in some cases to freeze). This perspective is consistent with accounts from evolutionary psychologists (Cosmides & Tooby, 2000), according to which affects are "superordinate programs" that orchestrate responses to recurrent situations of adaptive significance in our evolutionary past (see Loewenstein, 2007 for a discussion of the utility of such a definition).

Our use of the term affect is also related to the distinction between expected emotions and immediate emotions (Loewenstein & Lerner, 2003; Loewenstein et al., 2001; Rick & Loewenstein, 2008). Expected emotions are emotions that are anticipated to occur in the future as a result of decisions but are not experienced in the moment. As expected consequences of decisions, to the extent that they are taken into account, therefore, expected emotions will enter into deliberation. Indeed, one interpretation of the standard consequentialist model of decision making is that people seek to create positive expected emotions and avoid negative expected emotions. Immediate emotions, in contrast, are experienced at the moment of decision and might be completely unrelated to the decision at hand, in which case they are referred to as "incidental" (Bodenhausen, 1993). Perhaps most important, although they are experienced while making a decision, immediate emotions are not affected by the choice that is made, and thus, under the usual rational-choice perspective, should be irrelevant to choices. But numer-

ous studies have found that immediate emotions do influence decision making (Ariely & Loewenstein, 2006; Lerner & Keltner, 2000; Lerner et al., 2004; Raghunathan & Pham, 1999; Wilson & Daly, 2003). A natural interpretation of the affective system in our model is that it captures the influence of immediate emotions.

Finally, our use of the term affect (in contrast to deliberation) can be illustrated by the distinction that Kent Berridge (1996) draws between "wanting" and "liking." Wanting refers to an immediate motivation to acquire something or engage in some activity. Liking, in contrast, refers to how much one actually ends up enjoying the good or activity. Under this interpretation, our affective system makes decisions based on wanting, whereas our deliberative system makes decisions based on liking. Berridge indeed finds that wanting and liking are mediated by different, albeit overlapping, neural systems.

Note that our distinction between affect and deliberation does not imply that basic cognitive processes, such as those involved in object representation, memory, and attention, are absent in affective decision making. It is clear that these processes must play a role in any type of decision. We use the labels deliberation and affect primarily as labels to help organize two different types of motivations. Human behavior is driven by many different motivations in the brain, and restricting attention to two is clearly a simplification. Our point is that it can be a useful simplification to focus on two types of motivations, some that are more reactive and long-term goal-oriented (which we label "deliberation"), and others that are more reflexive and influenced by emotions and short-term drives (which we label "affect").

To formalize our approach, we assume that there are two "objective functions" operating simultaneously. Specifically, consider an individual who must choose an option *x* out of some choice set *X*. On one hand, the affective system

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[1] Throughout this article, we will use findings in neuroscience to motivate our framework of dual-process decision making. However, it is important to note that brain processes do not always map one-to-one onto psychological processes or behaviors. A more rigorous link between these findings, and the framework that we propose in this article, needs to be based on a formal model of the neurobiological basis of decision making (see, e.g., Yechiam, Busemeyer, Stout, & Bechara, 2005, for a discussion).

is motivated to engage in certain behaviors, and we capture these motivations with a motivational function, $M(x, a)$. The variable a captures the intensity of affective motivation. If the affective system alone were completely in charge of behavior, the affective system would "choose" $x^A \equiv \text{argmax}_{x \in X} M(x, a)$, which we refer to as the *affective optimum*. On the other hand, the deliberative system evaluates behavior with a broader and more goal-oriented perspective, and we capture the desirability of actions as perceived by the deliberative system with a utility function, $U(x)$. If the deliberative system alone were completely in charge of behavior, the deliberative system would choose $x^D \equiv \text{argmax}_{x \in X} U(x)$, which we refer to as the *deliberative optimum.* Typically, however, neither system is completely in charge of behavior. Hence, to make predictions, we must incorporate sources of divergence between the two systems, and explain how the two systems interact to generate behavioral outcomes.

Environmental Stimuli

Both systems are influenced by environmental stimuli. In some cases, the two systems will respond to the same stimuli with similar motivational tendencies. For example, during a break at a conference, the availability of a snack might create a surge of hunger in the affective system and be perceived by the deliberative system as a welcome opportunity to recharge before the next session. However, because the two systems operate according to quite different principles, in other situations the same stimulus can influence the two systems differently. If the conferee is on a diet, for example, the availability of the snack might also remind her of that fact, leading to a divergence of affective and deliberative motivation.

Existing research points to a number of factors that influence the strength of affective motivations while affecting the goals of the deliberative system much less if at all. Perhaps most important is the *temporal proximity* of reward and cost stimuli: Affective motivations are intense when rewards and punishments are immediate but much less intense when they are temporally remote. Deliberation is, in contrast, much less sensitive to immediacy. The importance of immediacy for affect has been documented in countless studies. Berns et al. (2006), for example, scanned the brains of subjects as

they were waiting to receive electric shocks of different intensities. They found that several affective regions known to respond to the experience of pain (such as the posterior insula, the amygdala, and the caudal anterior cingulate cortex) also responded to the anticipation of pain, and that the activation of these regions increased dramatically as the shock approached in time. Ichihara-Takeda and Funahashi (2006) similarly found that the activity in the orbitofrontal cortex, an area associated with the experience of affective reward, reached its peak immediately prior to the arrival of the reward. In contrast, deliberative areas, such as the dorsolateral prefrontal cortex, did not show this type of time dependence.

In addition to temporal proximity, various forms of *nontemporal proximity* have similar effects (Lewin, 1951). Thus, for example, a tempting snack is more likely to evoke hunger to the extent that it is nearby, visible, or being consumed by someone else. Early evidence on the role of nontemporal proximity comes from a series of classic studies conducted by Walter Mischel and colleagues (see, for instance, Mischel et al., 1972, 1989, 2003). Children were presented with a snack and told they could receive a larger snack if they waited until the experimenter returned. In a baseline treatment, children had the larger delayed snack positioned in front of them as they waited for the experimenter. Relative to this baseline treatment, children were able to delay significantly longer when the larger snack was not present, or even when the larger snack was present but covered. Research on construal-level theory (Trope & Liberman, 2003) also documents a distinction between proximate and nonproximate factors and provides evidence that level of construal plays a role in the relationship between nontemporal proximity and affective responses.

A third factor is the *vividness* of stimuli, by which we mean the ability to conjure the experience in mind. Researchers who study the impact of incidental emotions have become increasingly expert at evoking emotion, and many of the manipulations play on vividness by, for instance, showing people movies of an emotion-evoking event (Lerner et al., 2004), having people write essays in which they imagine themselves in a situation (Lerner & Keltner, 2000), playing music (Blood & Zatorre, 2001; Halberstadt & Niedenthal, 1997), or even through the

artful use of odors (Ditto et al., 2006; Zald & Pardo, 1997). The ability to evoke emotion through vividness suggests that vividness of different choice object and different experiences may play a crucial role in driving the responses of the affective system (see, however, Taylor & Thompson, 1982, for a discussion of limits on the impact of vividness on judgment).

To incorporate these three effects into our model, the motivational function, $M(x,a)$, incorporates a variable a that captures the *intensity* of affective motivations. In general, the larger is a, the stronger will be the affective motivations. In abstract terms, if the affective system prefers an option x over an option x', then an increase in affective intensity increases affective motivation in the sense that the difference $M(x, a) - M(x',a)$ increases with a. For some choice problems, there will be competing affective motivations, in which case a should be thought of as a vector of good-specific affective intensities. For instance, if one must make trade-offs between money and cookies, it would be natural to assume that $a = (a_M, a_C)$, where a_M is affective intensity for money, and a_C is affective intensity for cookies. Each affective intensity influences the motivation for its associated good.[2]

Behavioral Outcomes

A range of evidence suggests that the affective system holds a primacy in determining behavior—that is, the affective system has default control of behavior, but the deliberative system can step in to exert its influence as well. For instance, Joseph LeDoux and his colleagues (LeDoux, 1996) have demonstrated that fear responses are influenced by two separate neural pathways from the sensory thalamus to the amygdala (a lower-brain structure that plays a critical role in fear responses). One pathway goes directly from the sensory thalamus to the amygdala, and the second goes first from the sensory thalamus to the neocortex and from there to the amygdala. Moreover, they also discovered that the direct pathway is about twice as fast as the indirect pathway. As a result, rats can have an affective reaction to a stimulus before their cortex has had the chance to perform more refined processing.

When deliberation gets involved, what determines the extent to which it influences behavior? There is, in fact, compelling evidence that

deliberation does not easily take full control. Rather, when in conflict with affect, deliberative control, to the extent that it is possible, requires an expenditure of effort. The most important evidence along these lines comes from research by Baumeister and colleagues on willpower (for a summary, see Baumeister & Vohs, 2003), by which they mean an inner exertion of effort required to implement some desired behavior. Their basic contention is that such willpower is a resource in limited supply (at least in the short run), and that depletion of this resource by recent use will reduce a person's ability to implement desired behaviors. Baumeister's basic willpower paradigm involves having subjects carry out two successive, unrelated tasks that both require willpower and comparing the behavior on the second task to that of a control group that had not performed the first task. The general finding is that exerting willpower in one situation tends to undermine people's propensity to use it in a subsequent situation. In one representative study, for example, subjects who sat in front of a bowl of cookies without partaking subsequently gave up trying to solve a difficult problem more quickly than did subjects who were not first tempted by the cookies.

Because the target behaviors in Baumeister's studies— for example, not eating cookies or trying to solve a difficult puzzle—typically involve pursuit of broader goals, whereas not doing these behaviors typically involves indulging affective motivations, we believe there is a natural interpretation of these results for our model. Specifically, it is attempts by the deliberative system to override affective motivations that require an inner exertion of effort or willpower. Subsequently, if a person's willpower is depleted by recent use, the deliberative system will have less influence over behavior. Consistent with this view, a related line of research shows that simply making decisions can undermine willpower (Baumeister & Vohs, 2003).

Hence, one situation in which affect will have more sway over behavior is when the delibera-

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[2] Both here and in the section on risky decision making, we talk in terms of good-specific affective intensities. This language, however, should be viewed as a shorthand for an underlying model with (a) multiple types of affects (e.g., hunger, greed, fear, etc.) and (b) different types of goods that are differentially affected by different types of affect.

tive system is "worn out" from past willpower use. A second, related, situation is when the deliberative system is currently occupied by unrelated cognitive tasks. Research has shown that having subjects perform simple cognitive tasks—an intervention labeled "cognitive load"—undermines efforts at self-control. In one study, Shiv and Fedorikhin (1999) had subjects memorize either a 7-digit number (high cognitive load) or a 2-digit number (low cognitive load) before presenting them with a choice between cake (a high-calorie food) and fruit (a low-calorie food). Fifty-nine percent chose the cake in the high-load condition, but only 37% in the low-load condition.

To formalize these ideas, we assume that the deliberative system makes the final choice, but it must make this choice subject to having to exert effort—willpower—to control affective motivations. We capture this cognitive effort by assuming that, to induce some behavior different from the affective optimum (i.e., to choose an $x \neq x^A$), the deliberative system must exert an effort cost, in utility units, of $h(W, \sigma) * [M(x^A, a) - M(x, a)]$. This formulation assumes that the further the deliberative system moves behavior away from the affective optimum, the more willpower is required. The factor $h(W, \sigma) > 0$ represents the cost to the deliberative system of mobilizing willpower—that is, the higher is $h(W, \sigma)$, the larger is the cognitive effort required to induce a given deviation from the affective optimum.

Based on our discussion, we incorporate two factors that make it more costly for the deliberative system to exert willpower. The first is the person's current *willpower strength*, which we denote by W. This variable is meant to capture the current stock of willpower reserves; we assume that h is decreasing in W, so that as one's willpower strength is depleted the deliberative system finds it more difficult (more costly) to influence the affective system. Our analysis in this article will focus on one particular implication with regard to willpower strength: The more willpower a person has used in the recent past, the more her current willpower strength will be depleted, and hence exerting willpower becomes more costly. The second factor that makes it more costly for the deliberative system to exert willpower relates to competing cognitive demands (such as those induced by cognitive load), which we denote by σ. Thus, we will assume that h is increasing in σ: If a person's

deliberative system is distracted by unrelated cognitive tasks, exerting willpower becomes more costly.

General Implications

We now combine the elements of our formalization to derive general implications of our model. To make a choice, the deliberative system trades off the desirability of actions—as reflected by its utility function $U(x)$—against the willpower effort required to implement them. Hence, the deliberative system will choose the action $x \in X$ that maximizes $U(x) - h(W, \sigma) * [M(x^A, a) - M(x, a)]$. Because the affective optimum x^A is not affected by the person's actual choice, this is identical to maximizing:

$$V(x) \equiv U(x) + h(W, \sigma) * M(x, a) \qquad (1)$$

It follows that the person will choose an option that is somewhere in between the deliberative optimum and the affective optimum (when x is a scalar, either $x^D \geq x \geq x^A$ or $x^A \geq x \geq x^D$). Exactly where behavior falls will depend on the cost of mobilizing willpower as captured by $h(W, \sigma)$. As the cost of willpower decreases, behavior will be closer to the deliberative optimum, and as it increases, behavior will be closer to the affective optimum.

Although we interpret our model as reflecting that the deliberative system chooses behavior subject to willpower costs, there is a second interpretation of our model that is more consistent with our discussion of affective primacy. Because the deliberative optimum x^D and the affective optimum x^A, are not affected by the person's actual choice, maximizing $V(x)$ is equivalent to minimizing $[U(x^D) - U(x)] + h(W, \sigma) * [M(x^A, a) - M(x, a)]$. Hence, our model can be interpreted as the minimization of a weighted sum of two costs: a cost to the deliberative system from not getting its optimum x^D, and a cost to the affective system from not getting its optimum x^A. In this interpretation, $h(W, \sigma)$ captures the relative weights of the two systems.

While we have motivated our model as a dual-process approach, in the end behavior is determined by a single "objective" function, $V(x)$. What is the value, then, of the dual-process approach? One way in which the dual-

process approach is useful is that it provides a natural interpretation of many behavioral outcomes. When evaluating risky prospects, people might cognitively believe that they should weight probabilities linearly, but then make choices that reflect an insensitivity to probabilities. When weighing some intertemporal indulgence such as a tasty but highly caloric morsel or a willing but forbidden sexual partner, people might cognitively think that the indulgence is not worth the future costs, but then indulge nonetheless. Our model provides a natural interpretation: People's beliefs for what they ought to do reflect only the objectives of the deliberative system, whereas actual behavior is influenced by affective motivations as well. In other words, many deviations from the standard prescriptive models of decision making can be interpreted as coming from the motivations of the affective system.

A second way in which the dual-process approach is useful is that it provides a template for interpreting research from neuroscience. Recent research in neuroscience, particularly in the subdiscipline of neuroeconomics, often focuses on where we see brain activity when people make decisions. And, while neuroscientists are often interested in more fine partitions, a frequent focus is on the extent to which activity occurs in the prefrontal cortex or in evolutionarily older brain systems, such as the amygdala, the hypothalamus, and other parts of the limbic system. To the extent that our deliberative system is roughly meant to capture activity in the prefrontal cortex whereas our affective system is roughly meant to capture activity in the evolutionarily older brain systems, according to our model such research can be used to shed insight on the different objectives of the two systems. Indeed, we have already discussed some neuroscientific research in this way, and do so further in the discussion of specific applications.[3]

But perhaps the most important value of the dual-process approach is that it generates testable predictions. These predictions are perhaps most clear when a person faces a binary choice between two options. Suppose a person is choosing between an option x and an option x', where option x is the deliberative optimum (i.e., $U(x) > U(x')$. According to our model, the person will choose the former when $U(x) + h(W, \sigma)M(x, a) > U(x') + h(W, \sigma)M(x', a)$, or $U(x) - U(x') > h(W, \sigma)[M(x', a) - M(x, a)]$.

First note that if option x is also the affective optimum, i.e., $M(x, a) > M(x', a)$, then the person will clearly choose option x. Hence, assume instead that option x' is the affective optimum, i.e., $M(x', a) > M(x, a)$. From the inequality, two general predictions follow:

> *General Prediction #1:* If a person faces a binary choice between options x and x' where option x is the deliberative optimum while option x' is the affective optimum, then willpower depletion or unrelated cognitive demands such as cognitive load increase the cost of exerting willpower [increase $h(W, \sigma)$] and therefore make it less likely that the person chooses the deliberative optimum (option x).

> *General Prediction #2:* If a person faces a binary choice between options x and x' where option x is the deliberative optimum and option x' is the affective optimum, then if increased affective intensity increases the affective preference for option x' over option x [i.e., if increased a increases the difference $M(x', a) - M(x, a)$], then affective intensity makes it less likely that a person chooses the deliberative optimum (option x). If, instead, affective intensity decreases the affective preference for option x' over option x[i.e., if increased a decreases the difference $M(x', a) - M(x, a)$], then an increase in affective intensity makes it more likely that a person chooses the deliberative optimum (option x).

In the next three sections, we apply our model to three specific domains: intertemporal choice, risky decision making, and social preferences. In each domain, we make specific assumptions about the objectives of the two systems and use these to derive specific predictions of our model. In some cases, we find existing evidence that supports these predictions, but in others we propose them as testable, but as yet untested, predictions of the model.

Intertemporal Choice

The most straightforward application of our model is to intertemporal choices—decisions that involve tradeoffs between current and future outcomes. Suppose that each option x in the choice set X generates a stream of payoffs $x_1, x_2,$

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[3] Note of course that many fMRI studies in neuroscience are correlational, and that activation in a particular brain area cannot always justify inferences regarding the underlying psychological processes at play in observed behavior. That said, we believe that our approach is a desirable first step in incorporating neuroscientific research into the study of emotion and deliberation in preferential choice, and that much of this research serves as a valuable complement to the psychological and behavioral findings that we discuss in this article.

$\ldots$, x_T, where payoff x_t is received in period t, and all payoffs involve the same type of choice option. For simplicity, and for comparison to standard approaches in economics, we assume that both the affective and the deliberative systems display standard exponential discounting. However, we additionally assume that the affective system is more myopic than the deliberative system (and sometimes consider the special case where the affective system cares only about immediate outcomes), and we also assume that increased affective intensity makes the affective system more myopic.[4]

Formally, we assume that the deliberative system's utility function is $U(x) = x_1 + \delta_D x_2 + \ldots + [\delta_D]^T x_T$; that is, exponential discounting with discount factor δ_D. The affective system's motivational function is $M(x, a) = x_1 + \delta_A(a)x_2 + \ldots + (\delta_A(a))^T x_T$; that is, exponential discounting with discount factor $\delta_A(a)$. We further assume that $\delta_A(a) < \delta_D$, and that increased affective intensity a implies a smaller $\delta_A(a)$ and thus more myopia. Putting these together, the decision maker will choose x to maximize:

$$V(x) = [x_1 + \delta_D x_2 + \ldots + [\delta_D]^T x_T] + h(W, \sigma)$$
$$*[x_1 + \delta_A(a)x_2 + \ldots + [\delta_A(a)]^T x_T]$$

$$(2)$$

Our assumption that the affective system is driven primarily by short-term payoffs, whereas the deliberative system cares about both short-term and longer-term payoffs is similar to that made by existing dual-process theories of intertemporal choice in economics (Benhabib & Bisin, 2005; Bernheim & Rangel, 2004; Fudenberg & Levine, 2006; Shefrin & Thaler, 1988; Thaler & Shefrin, 1981). There is considerable evidence in support of this assumption. On the deliberative side, Frederick (2003) asked subjects how they believed they should respond to outcomes occurring at different times, and most people generally believed that time discounting is not normatively justified—that outcomes should receive the same weight regardless of when they occur. This suggests that people perceive their own impulsivity as contrasting with what they believe to be reasonable.

On the affective side, when animals are presented with intertemporal choices, they are extremely myopic. There is a long literature that demonstrates extreme myopia in pigeons and rats. Indeed, it has been found that species of New World monkeys are willing to wait less than 20 s for a food reward that is three times as large (Stevens et al., 2005). Monkeys that are closer, evolutionarily, to humans show less although by human standards still extreme levels, myopia (Tobin et al., 1996). In a related vein, children have been shown to be more myopic than adults, with children and teenagers exhibiting much steeper discount functions that individuals in their 20s and 30s (Steinberg et al., 2009). To the extent that animal and child behavior can be used to shed insight on the motivations of humans' affective system, this evidence suggests that the affective system is myopic, and that concern for longer-term outcomes are a product of the deliberative system.

More convincing evidence comes from neuroscience. McClure et al. (2004, 2006) scanned subjects' brains using fMRI while they made choices between smaller-sooner rewards versus larger-later rewards. All of these choices produced activation in prefrontal regions associated with deliberation (such as the dorsolateral and ventrolateral prefrontal cortex); however, when one of the options involved an immediate reward, brain regions associated with affective processing, such as the ventral striatum and medial orbitofrontal cortex, also became activated. Moreover, in situations in which an immediate reward was one of the options, higher relative activation of the affective regions increased the likelihood that the subject would choose the immediate reward.

Similar results are suggested by Bjork et al. (2009), who found that delay discounting can be predicted by the size of the decision maker's lateral prefrontal cortex. Figner et al. (2010) also found that experimentally disrupting prefrontal areas associated with deliberation (particularly the lateral prefrontal cortex) led to an increased choice of immediate rewards over delayed rewards. This disruption did not, however, alter choices between delayed rewards, suggesting that deliberative processing plays a

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[4] Our key predictions, I-1 and I-2, rely only on the assumption that the affective system is more myopic than the deliberative system, and not on the assumption of exponential discounting. We assume exponential discounting to highlight how our framework can give rise to hyperbolic discounting, even if neither system exhibits hyperbolic discounting (as we discuss later).

fundamental role in directing nonmyopic choice.

Last, considerable research on addiction and self-control has documented a discrepancy between an addict's short-term desires (involving, e.g., the consumption of an addictive substance), and an addict's long-term goals (which seek to regulate cravings and stop the use of these addictive substances; see, e.g., Goldstein, 2001 for a discussion). This pattern of behavior strongly supports the assumptions of affective myopia and deliberative far-sightedness that we propose in this article.

Equation 2 yields several important predictions. First, maximizing Equation 2 is equivalent to maximizing $\tilde{V}(x) = x_1 + \sum_{t=1}^{\infty} D(t)x_{1+t}$ with:

$$D(t) = \frac{(\delta_D)^t + h(W, \sigma)(\delta_A(a))^t}{1 + h(W, \sigma)}.$$

Note that $D(t)$ is a discount function reflecting the discounting associated with a payoff with delay t. This formulation (with $\delta_D > \delta_A(a)$) implies both discounting (i.e., that $D(0) = 1 > D(1) > D(2) \ldots$) and declining discount rates (i.e., $D(0)/D(1) > D(1)/D(2) > D(2)/D(3) \ldots$). In addition, in the special case where $\delta_A(a) = 0$, maximizing Equation 2 is equivalent maximizing $x_1 + \beta\delta x_2 + \ldots + \beta\delta^T x_T$, where $\beta = 1/(1+h(W, \sigma)) < 1$. This is the well-known beta-delta function used by Laibson (1997) and others, as an analytical tractable simplification of hyperbolic discounting.[5]

Hence, our model, with the assumption that affective discounting provides a natural interpretation—or reinterpretation—of (quasi) hyperbolic discounting. Specifically, even if the deliberative system discounts exponentially, because behavior is also influenced by a more myopic affective system, people will be more impatient when facing now versus near-future trade-offs than they will be when facing future versus further-future trade-offs—which is the essence of hyperbolic discounting. This formulation also implies that a decrease in willpower, increase in cognitive demands, or increase in affective intensity will lead to a higher value of β without changing the effective δ. The quasi-hyperbolic form defined here is consistent with a number of intertemporal preference reversals (e.g., Ainslie, 1975; Kirby, 1997), with de-

clining (average) discount rates (e.g., Ben-Zion, Rapoport, & Yagil, 1989; Thaler, 1981), as well as with evidence (e.g., Frederick et al., 2002) suggesting that the magnitude of discounting is based on the distinction between now and the future—and in particular, that people exhibit nearly constant discounting when facing two future trade-offs.

Beyond providing an alternative account of hyperbolic time discounting, Equation 2 also generates testable predictions by applying the two general predictions of our model:

> *Intertemporal Choice Prediction #1 (I-1):* An increase in $h(W, \sigma)$ will lead to more myopic behavior.

> *Intertemporal Choice Prediction #2 (I-2):* Any factor that increases the intensity of the affective motivation for the immediate payoff will lead to more myopic behavior.

The increases to myopic behavior listed in Predictions I-1 and I-2 will affect choice only when the decision involves tradeoffs between immediate and future payoffs. Willpower, cognitive load, or affective intensity will not alter tradeoffs involving two or more future payoffs. In addition, note that Predictions I-1 and I-2 also hold for the more general model, which allows the affective system to discount exponentially (but with a lower discount factor than that displayed by the deliberative system).

There is existing evidence on Predictions I-1 and I-2. For instance, Vohs and Heatherton (2000) investigated how willpower depletion affects the amount of ice cream people eat when asked to taste and rate three flavors. To the extent that eating ice cream involves immediate benefits and future costs, eating more ice cream can be taken to reflect increased myopia. In support of I-1, they found that, among dieters, willpower depletion led subjects to eat more ice cream. However, they found no effect among nondieters. In addition, Vohs and Faber (2007) found that willpower depletion led to increased impulse buying, and Vohs et al., (2008) found

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[5] Mathematically hyperbolic discounting is described with the discount factor $1/(1+kt)$. The beta-delta approximates this formulation in discrete time. For β and δ between 0 and 1, the decision maker will be present biased when choosing between immediate and delayed rewards, but will discount exponentially when choosing between different delayed rewards. Note that some scholars have argued against discounting models, in favor of attribute tradeoff models (Scholten & Read, 2010).

that willpower depletion increased procrastination. Finally, more direct evidence of the impact of willpower depletion on delay discounting is documented by Vohs et al. (2013). Individuals who performed depletion tasks prior to making intertemporal choices were more likely to choose smaller, immediate rewards over larger, delayed rewards.

The Shiv and Fedorikhin (1999) study earlier in this article provides support for the cognitive demands Prediction of I-1—specifically, cognitive load makes subjects more prone to choose cake over fruit, reflecting increased myopia. Benjamin, Brown, and Shapiro (2013) provide more direct evidence. They asked Chilean high school juniors to make a series of short-term trade-offs and long-term trade-offs for monetary payoffs. Relative to control subjects, subjects who answered these questions while under cognitive load showed nontrivial reductions in short-term patience. In contrast, cognitive load had no effect on long-term patience.

I-2 captures a host of predictions based on the different factors, discussed above, that increase affective intensity. Most straightforwardly, our model predicts that nontemporal proximity of immediate outcomes should play a large role in elicited discount rates. Thus, for example, the extent that an immediate reward can be seen or smelled will affect the magnitude of discount rates that people's behavior reveals, which is consistent with the research by Mischel and colleagues described earlier in this article. Note that Mischel's results are puzzling when viewed from the perspective of hyperbolic discounting. As time passes, and thus the delay between the immediate smaller snack and the delayed larger snack shrinks, children become less willing to wait (which is why many children initially decide to wait, but then "bail out")—exactly the opposite of what hyperbolic discounting would predict. Willpower depletion, however, provides a natural explanation. Specifically, as time passes and the person's willpower is slowly depleted, eventually they no longer have enough willpower to support further delay.

Indeed, our framework provides a natural formalization of this behavioral pattern. Specifically, let τ denote the time for which a child has been waiting, let $W(\tau)$ denote the willpower remaining at time τ, and make the natural as-

sumption that have $dW/d\tau < 0$—because waiting takes willpower and thus willpower declines over time. Letting x denote the deliberative optimum (waiting) and x' denote the affective optimum (getting the snack now), the person will wait only if $U(x) - U(x') > h(W(\tau), \sigma)$ $[M(x', a) - M(x, a)]$. As time passes (τ increases) and willpower depletes ($W(\tau)$ declines), this condition becomes less and less likely to hold.

Our framework can similarly explain why decision makers are more likely to succumb to temptation when they are repeatedly confronted with tempting choices. Not only are temptation and willpower likely to fluctuate over time, allowing for more opportunities for temptation to overcome willpower, but also because resisting temptation depletes willpower, and doing so repeatedly depletes it proportionately.

Giordano et al. (2002) provide additional evidence in support of I-2. They measured the time discounting of heroin addicts for both money and heroin, both when the addicts were satiated (after they had received treatment with an opioid agonist) and when they were deprived (before receiving treatment). They observed greater time discounting for heroin than for money, and greater discounting of both types of reward when the addicts were opioid-deprived than when they were satiated. Johnson et al. (2007) similarly found that smokers discount cigarettes more than they discount money or health, and Rosati et al. (2007) found that individuals are more impatient for food relative to money. These results are consistent with our framework as long as heroin, food and cigarettes have higher affective intensity than money (and have even higher affective intensity when decision makers are in a state of craving or hunger).

Finally, I-2 predicts that people who have particularly strong affective reactions to stimuli will exhibit more myopic behavior. In fact, direct support for this prediction comes from research by Hariri et al. (2006), who found that people who exhibited larger affective reactions to random monetary gains and losses in one experimental session (as measured by neural activation in the ventral striatum) also showed increased myopia when trading off

immediate versus future monetary payoffs in a different experimental session.

Risky Decision Making

A second natural application of our model is to choices between risky prospects. To apply our two-system approach to risky decision making, we must make assumptions about how the two systems respond to risks. For the deliberative system, a natural assumption is that risks are evaluated according to their expected utility (or perhaps expected value). Indeed, most researchers, as well as knowledgeable lay people, agree that expected-utility theory is the appropriate prescriptive theory to use for evaluating risks (for a discussion, see Bleichrodt et al., 2001). It is less obvious what drives the affective system, but we suggest that insensitivity to probabilities and loss aversion—two prominent features in many descriptive theories of risk preferences (Starmer, 2000)—derive from the affective system.

Suppose that each option x in the choice set X is a lottery $x \equiv (x_1, p_1; \ldots; x_N, p_N)$, where outcome x_i occurs with probability p_i. We assume that the deliberative system's utility function is $U(x) = \sum p_i u(x_i)$. In some subsequent analyses, we assume that $u(x_i) = x_i$ (i.e., the deliberative system cares about expected value) whenever choosing between monetary gambles. This does not affect any of our results; it only makes it easier to illustrate the effects of incorporating the affective system into a model of risky choice.

The affective system, in contrast, has motivational function $M(x, a) = \sum w(p_i) v(x_i, a)$, where $w(p_i)$ is a nonlinear probability-weighting function, and $v(x_i, a)$ is a value function that incorporates loss aversion. For simplicity, we assume the value function is $v(x_i, a) = au(x_i)$ if x_i is a gain, and $v(x_i, a) = a \lambda u(x_i)$ if x_i is a loss, where the variable $\lambda > 1$ reflects the degree of loss aversion. For the probability-weighting function, many of our results don't require a specific assumption, and thus we often use a generic $w(p)$. However, we believe that the key feature is that the affective system is less sensitive to probabilities than the deliberative system, that is, $dw/dp < 1$ for $p \in (0, 1)$. In our analysis, we sometimes use the specific example of $w(p) = c + bp$ for all $p \in (0, 1)$, $w(0) = 0$, and $w(1) = 1$, where $c > 0$ and $c < 1 - b$.[6]

Incorporating these functions into Equation 1, the person will choose the option x that maximizes

$$V(x) = \sum p_i u(x_i) + h(W, \sigma) * \left[\sum w(p_i) v(x_i, a) \right].$$

(3)

The assumptions underlying Equation 3 come from diverse lines of research from a range of disciplines and resemble some of the assumptions made in Mukherjee (2010). There is strong physiological evidence that supports our contention that the affective system exhibits insensitivity to variation in probabilities. Studies that measure fear by means of physiological responses such as changes in heart rate and skin conductance—which primarily reflect activity in the affective system—find that reactions to an uncertain impending shock depend on the expected intensity of the shock but not the likelihood of receiving it (except if it is zero; Bankart & Elliott, 1974; Deane, 1969; Elliott, 1975; Monat et al., 1972; Snortum & Wilding, 1971). Other evidence supports the idea that emotional responses result largely from *mental images* of outcomes (Damasio, 1994). Because such images are largely invariant with respect to probability—one's mental image of winning a lottery, for example, depends a lot on how much one wins but not that much on one's chance of winning—emotional responses tend to be insensitive to probabilities.

There is also evidence that supports our contention that loss aversion derives from the affective system. For instance, Chen et al. (2006) introduced a currency into a colony of capuchin monkeys, presented the monkeys with gambles, and found that the monkeys displayed loss aversion. To the extent that animal behavior is indicative of the output of the human affective system, this result suggests that loss aversion, and the behaviors that it generates, derives from the affective system. Of course, there are many other differences between human and animal risk taking that are attributable to factors other

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[6] Note that our assumption $dw/dp < 1$ for all $p \in (0, 1)$ will require a discontinuity at $p = 0$ and at $p = 1$, much as was suggested in the original version of prospect theory (Kahneman & Tversky, 1979).

than affective strength. For example, Weber et al. (2004) found that some differences between human and animal behavior in the domain of risk disappear when differences in reward learning are controlled for.

There is also neuroscientific evidence. Tom et al. (2007) collected fMRI data while subjects decided whether to accept or reject gambles that involved a chance to win or lose various amounts of money. The gambles differed in the magnitudes of the gains and losses, and the researchers found that affective regions, such as the striatum and medial orbitofrontal cortex, react to these changes. Moreover, these regions display a neural loss aversion: The increase in activity when the gain amount increases is smaller than the decrease in activity when the loss amount increases. Similar results have also been documented by Weber et al. (2007), who found that the amygdala is differentially active when decision makers are parting with goods. In addition, Sokol-Hessner, Camerer, and Phelps (2013) found that the reappraisal of choices involving loss aversion generates increased activity in the dorsolateral and ventrolateral prefrontal cortex and reduced activity in the amygdala. Regulating loss aversion, according to this research, involves the suppression of emotion by the deliberative system.

The relationship of affect with loss aversion has also been shown to be responsible for nonrisky reference dependence anomalies, such as the endowment effect. Particularly, Knutson et al. (2008) found that activity in limbic system regions, such as the nucleus accumbens, which play an important role in loss averse behavior, also predict individual susceptibility to the endowment effect. Individuals who showed increased affective sensitivity to losses were also most likely to display discrepancies between acceptable buy and acceptable sell prices.

Another piece of neuroscientific evidence for the role of affect in loss aversion comes from a study by Shiv et al. (2003), who compared healthy people; patients with brain lesions in regions related to emotional processing, such as the amygdala and the orbitofrontal cortex (they were normal on most cognitive tests, including tests of intelligence); and patients with lesions in regions unrelated to emotion. Patients with emotion-related lesions were more likely to select risky gambles (involving losses) than other subjects—that is, they exhibited less loss aversion—and ul-

timately earned more money, suggestive of the idea that the emotional processing regions that were damaged play a role in loss aversion. Moreover, whereas normal people and patients with lesions unrelated to emotion were influenced by their outcomes in previous rounds, patients with emotion-related lesions were not. These results have also been documented by De Martino, Kumaran, Seymour, and Dolan (2010). De Martino and coauthors estimated loss aversion coefficients for two individuals with amygdala damage. Using a series of gambles with gains and losses ranging from $20 to $50, they found that estimated loss aversion coefficients for the two patients were very close to one, indicating an absence of loss aversion.

Predictions

The general model presented earlier will yield predictions that reflect three rough intuitions. First, because insensitivity to probabilities and loss aversion derive from the affective system, willpower depletion or unrelated cognitive demands, such as cognitive load, will magnify these behavioral tendencies. Second, if a person faces a choice between lotteries for which all outcomes involve the same type of good and thus the same affective intensity, then an increase in that affective intensity will also magnify insensitivity to probabilities and loss aversion. Finally, if a person faces a choice between lotteries that involve different goods and thus different affective intensities, then the effects of affective intensity are good-specific. To translate these rough intuitions into specific predictions, we apply our model, as specified in Equation 3, to specific risky choices.

Monetary Certainty Equivalent for Monetary Gambles

Suppose a person faces a simple gamble (Z, p; $0,1-p$) with $Z > 0$, and we elicit the person's monetary certainty equivalent—that is, the certain amount CE such that the person is indifferent between the gamble and that certain amount. Tests for nonlinear probability weighting often focus on these types of choices, and in particular on how overweighting of small probabilities should lead to $CE > pZ$, whereas underweighting of large probabilities should lead to $CE < pZ$.

This type of choice has two simplifying features. First, because all outcomes involve a monetary payoff, the same affective intensity for money, which we denote by a_M, is applied to all outcomes. Second, because $Z > 0$ and therefore $CE > 0$, and because we assume for monetary outcomes that $u(x) = x$, we can ignore loss aversion, and the value function merely becomes $v(x_i, a) = a_M x_i$. Hence, according to our model, the monetary certainty equivalent is determined by $CE + h(W, \sigma)[a_M CE] = pZ + h(W, \sigma)[w(p)a_M Z]$, which yields that $CE = \tilde{w}(p)Z$ where

$$\tilde{w}(p) = \begin{cases} 0 & \text{if } p = 0 \\ \dfrac{p + h(W, \sigma)\, a_M\, w(p)}{1 + h(W, \sigma)\, a_M} & \text{if } p \in (0, 1) \\ 1 & \text{if } p = 1 \end{cases}$$

Much as in expected utility and prospect theory, the certainty equivalent is derived from multiplying the magnitude of the outcome by a weight that is a function of the probability of that outcome. However, the probability weighting function for each of the three models is different. Under expected utility with linear utility for money, $CE = pZ$ (i.e., linear weighting of probabilities), and under prospect theory with a linear value function in the gain domain, $CE = \tilde{w}(p)Z$, where $\tilde{w}(p)$ is prospect theory's probability-weighting function. Figure 1 presents an example of an effective weighting func-

tion implied by our model when the affective system's weighting function $w(p)$ is assumed to be linear with a positive intercept and a slope less than 1 (reflecting an insensitivity to probability changes). In particular, it depicts (a) the weight used by the deliberative system (p), (b) the weight used by the affective system, $w(p)$, and (c) the effective weight used for decisions, $\tilde{w}(p)$. Notice that our model is closer in spirit to Kahneman and Tversky's original formulation in being ill defined at the extremes (in fact, Barseghyan et al., 2013 estimates probability weighting from data on insurance deductible choices and seems to find support for Kahneman and Tversky's original formulation).

Like prospect theory, if affective motivations generate an overweighting of small probabilities and underweighting of large probabilities, as reflected in $w(p)$, then our model predicts $CE > pZ$ for $p < \pi$ and $CE < pZ$ for $p > \pi$. However, unlike expected utility and prospect theory, which assume fixed probability weighting functions, our model generates novel testable predictions for factors that should alter probability weighting and hence the certainty equivalent:

Risky Choice Prediction #1 (R-1): When generating a certainty equivalent for simple monetary gambles, an increase in $h(W, \sigma)$ will increase CE when $CE > pZ$ and decrease CE when $CE < pZ$.

Risky Choice Prediction #2 (R-2): When generating a certainty equivalent for simple monetary gambles, an increase in the intensity of affective motivation for
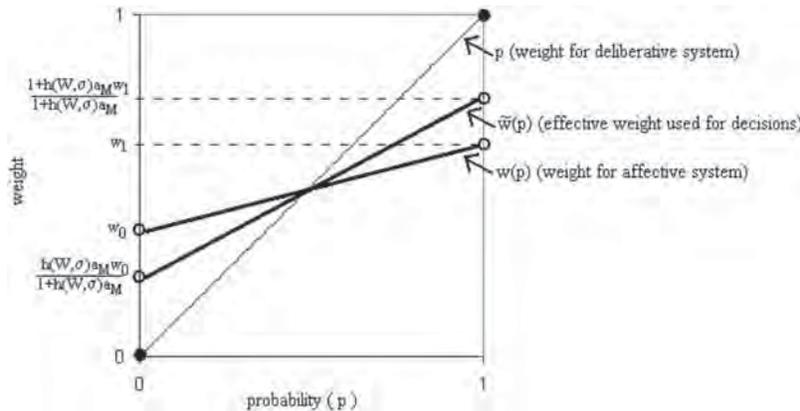

Figure 1. Effective probability weighting function $\tilde{w}(p)$ predicted by our model for certainty equivalents for monetary gambles when the affective system has probability weighting function $w(p) = w_0 + (w_1 - w_0) * p$ with $w_0 > 0$ and $w_1 < 1$.

money will increase CE when $CE > pZ$ and decrease CE when $CE < pZ$.

Intuitively, because deliberation argues for $CE = pZ$, if $CE > pZ$ then the affective system is dragging CE upward, and therefore when willpower depletion, cognitive load, or affective intensity for money give more sway to affect, it will drag CE further upward. Analogously, if $CE < pZ$, then the affective system is dragging CE downward, and therefore when willpower depletion, cognitive load, or affective intensity give more sway to affect, it will drag CE further downward. Hence, our model generates sharp predictions for these simple decisions; unfortunately, we know of no existing evidence on such effects.

Monetary Certainty Equivalent for Simple Nonmonetary Gambles

Suppose a person faces a simple gamble $(x, p; 0, 1 - p)$, where x is a nonmonetary good such as a plate of cookies, and again we elicit the person's monetary certainty equivalent for this gamble. Because this choice involves two distinct goods—for example, money versus cookies—we must distinguish between affective intensity for money, a_M, and affective intensity for x, which we denote by a_x. According to our model, the monetary certainty equivalent is determined by $CE + h(W, \sigma)[a_M CE] = pu(x) + h(W, \sigma)[w(p)a_x u(x)]$, which yields that $CE = \tilde{w}(p)u(x)$ where

$$
\tilde{w}(p) = \begin{cases}
0 & \text{if } p = 0 \\
\dfrac{p + h(W, \sigma) \, a_X \, w(p)}{1 + h(W, \sigma) \, a_M} & \text{if } p \in (0, 1) \\
1 & \text{if } p = 1
\end{cases}
$$

Figure 2 depicts the effective weighting function $\tilde{w}(p)$ here using the same affective system's weighting function $w(p)$ from Figure 1. While the effective weighting function here has the same qualitative shape as that in Figure 1, there is one important difference: whereas in Figure 1, $\tilde{w}(p) < p$ for p close enough to one, in Figure 2, it is possible to have $\tilde{w}(p) > p$ for all $p < 1$. Intuitively, there are two forces at work. First, just as for the certainty equivalent for simple monetary gambles, the affective system overweighs small probabilities, which tends to drag the

CE upward, and the affective system underweights large probabilities, which tends to drag the CE downward. Second, and unique for this case, affective intensity for the nonmonetary good might be larger than affective intensity for money, which tends to drag the CE upward. For low probabilities, these two effects reinforce each other, and thus affect drags the CE upward. For high probabilities, in contrast, the two forces oppose each other. If the former dominates, affect drags the CE downward (panel A of Figure 2); if the latter dominates, affect drags the CE upward (panel B of Figure 2). Because the impact of willpower depletion and unrelated cognitive demands, such as cognitive load, depend on whether affect is dragging the CE upward or downward, our model yields somewhat different predictions for the certainty equivalent for simple nonmonetary gambles than for simple monetary gambles (we are not aware of any existing evidence on these predictions):

> *Risky Choice Prediction #3 (R-3):* When generating a certainty equivalent for simple nonmonetary gambles, an increase in $h(W, \sigma)$ will increase CE when p is small, but when p is large, the effect is ambiguous.

Because the choice is between money versus a nonmonetary good, the implications of affective intensity are good-specific. In particular, an increase in the affective intensity for x will increase the affective system's motivation for x without changing its motivation for money, and thus increase the certainty equivalent. Analogously, an increase in the affective intensity for money will increase the affective system's motivation for money without changing its motivation for x, and thus decrease the certainty equivalent.

> *Risky Choice Prediction #4 (R-4):* When generating a certainty equivalent for simple monetary gambles, any factor that increases the intensity of the affective motivation for the non-monetary good will increase CE, whereas any factor that increases the intensity of the affective motivation for money will decrease CE.

The excessive reaction to affectively charged but unlikely outcomes that is predicted by our model can be seen in numerous domains of behavior, from gold rushes to market manias to the mating behavior of young adults. Less anecdotally, Ditto et al. (2006) offered participants choices between gambles for the chance
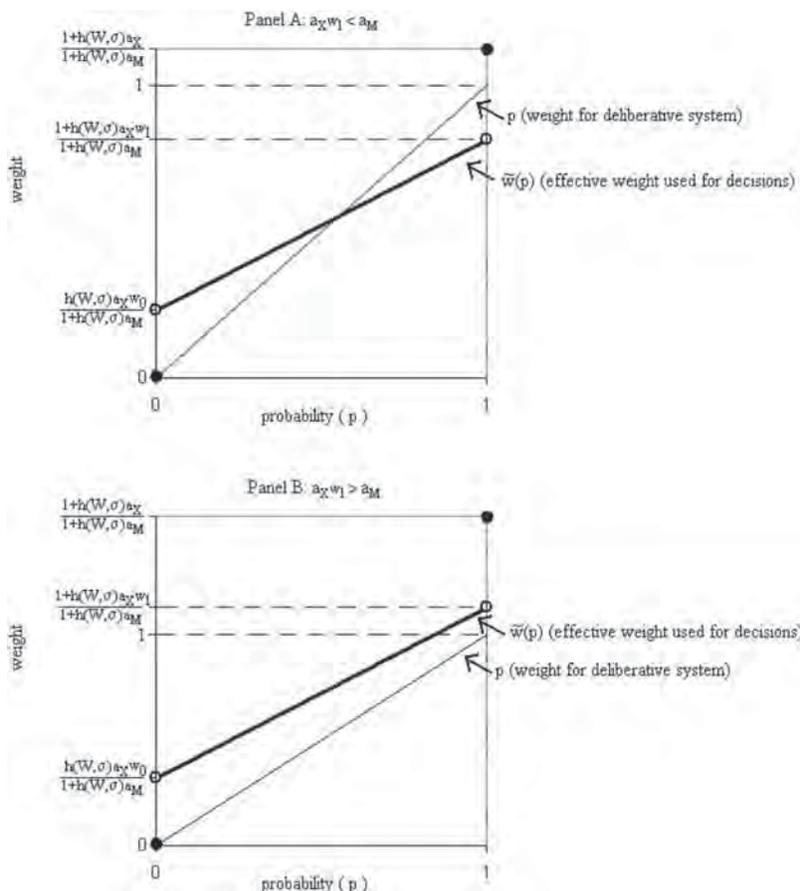
Figure 2. Effective probability weighting function $\tilde{w}(p)$ predicted by our model for certainty equivalents for nonmonetary gambles when the affective system has probability weighting function $w(p) = w_0 + (w_1 - w_0)^* p$ with $w_0 > 0$ and $w_1 < 1$.

to win chocolate chip cookies and various fixed outside options. Half of the participants were only told about the cookies, whereas for the other half the cookies were freshly baked in the lab and placed in front of participants as they made their decision. Just as our model (R-4) predicts that increased affective intensity for cookies will increase the monetary certainty equivalent, it also predicts that increased affective intensity for cookies will make people more likely to accept the gamble over an outside option. This is exactly what is found by Ditto et al. (2006, though their results hold only for the high risk gambles).

Another study (Rottenstreich & Hsee, 2001) compared certainty equivalents for simple gambles that involve affect-rich outcomes (such as

vacations and electric shocks) with certainty equivalents for simple gambles that involve affect-poor outcomes (such as money). In each case, they found that the certainty equivalent for the affect-rich outcome was larger than the certainty equivalent for the affect-poor outcome when the probability was very low (1%), but this result was reversed when the probability was very high (99%). From these results, they concluded that probability-weighting for affect-rich outcomes is more S-shaped than probability-weighting for affect-poor outcomes. In our model, affective intensity for the nonmonetary good does not directly translate into an effect on the probability-weighting function. Even so, these results are consistent with our model. In particular, according to our model, the increase

in probability from 1% to 99% will have a bigger effect on the affect-poor outcomes than on affect-rich outcomes as long as the deliberative system, which is the system influenced by the probability change, has a stronger reaction to the affect-poor outcome. For the case of gains, this means the deliberative system must prefer the affect-poor outcome (i.e., the utility of the affect-poor outcome is more positive), and in the case of losses, it means the deliberative system must prefer the affect-rich outcome (i.e., the utility of the affect-poor outcome is more negative). For the gambles studied by Rottenstreich and Hsee, both seem plausible.

Risk Preferences for Mixed (Gain-Loss) Gambles

Suppose a person must choose whether to accept a gamble ($G,1/2; –$L,1/2$) with $G,L>0$. Unlike the previous decision, such gambles involve both gains and losses, and thus loss aversion becomes relevant. According to our model, the person will accept when $\left[\frac{1}{2}(G) + \frac{1}{2}(-L)\right] + h(W, \sigma)[\pi(a_M G) + \pi(-a_M \lambda L)] > 0$, where $\pi = w(1/2)$ here. This generates the following predictions:

> *Risky Choice Prediction #5 (R-5):* When facing 50–50 gain-loss gambles with $L < G < \lambda L$, an increase in $h(W, \sigma)$ will make it more likely that the person rejects the gamble.

> *Risky Choice Prediction #6 (R-6):* When facing 50–50 gain-loss gambles with $L < G < \lambda L$, any factor that increases the affective intensity for money will make it more likely that the person rejects the gamble.

If $G \leq L$ then both systems prefer to reject, and if $G \geq \lambda L$ then both systems prefer to accept, and so in either case willpower depletion, cognitive load, and affective intensity are irrelevant. The interesting case occurs when $L < G < \lambda L$—when the gamble has a small but positive expected value—in which case the deliberative system prefers to accept while the affective system prefers to reject. In such cases, willpower depletion, cognitive load, or affective intensity all increase the influence of loss aversion and make it more likely that the person will reject the gamble. For simplicity, we have restricted the previous example to the settings where both the gain and the loss outcomes are equally likely. However, these insights hold for more general gambles as well (in which the

effect of willpower depletion, cognitive load, or affective intensity will depend on gain and loss probabilities, in addition to gain and loss magnitudes).

Although we are not aware of any evidence of the impact of willpower depletion on risk-taking behavior, Benjamin et al. (2013) provide some indirect evidence on the effects of unrelated cognitive demands, such as cognitive load. In addition to asking the time preference questions described previously, they also asked their subjects to make a series of risky choices. Relative to control subjects, subjects who answer these questions while under cognitive load showed substantial reductions in risk taking behavior. Similar results have also been documented by Whitney et al. (2008) who found that the probability of choosing a risky gamble over a safe gamble reduced under cognitive load. To the extent that small-stakes risk aversion derives from loss aversion (Rabin, 2000; Rabin & Thaler, 2001), these results are consistent with the prediction that increasing cognitive load will lead to increased loss aversion (Prediction R-5).[7]

The Endowment Effect

Even though it is not an example of risky decision making, the endowment effect—the tendency to value an object more highly when one owns it—is commonly attributed to loss aversion (e.g., Tversky & Kahneman, 1991), and thus our model has implications for the endowment effect. Suppose, as in many experimental demonstrations of the endowment effect, that we elicit two reservation values: (a) The *selling price* P_S is the price such that, if the person is initially endowed with an object, she will be indifferent between keeping the object and receiving $$P_S$. (b) The *choice price* P_C is the price such that, if the person is initially not endowed with an object, she will be indifferent between gaining the object and receiving $$P_C$. The typical finding in experiments is that, even though the choices are

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[7] Rabin and Thaler note that the preference for small-scale safe outcomes over small-scale risky outcomes observed in many laboratory experiments is inconsistent with the type of risky behavior observed for larger real-world stakes. Loss-aversion is a mechanism that can resolve this inconsistency.

the same—leaving the experiment with an object or with some money—the selling price is significantly larger than the choice price. To formalize this situation within our model, we assume, as done previously, that the deliberative system values money P as P and values the object x as $u(x)$. The deliberative system is not influenced by one's endowment. The affective system, in contrast, is sensitive to one's endowment. Specifically, when endowed, the affective system views the choice as [*gain P_S, lose $u(x)$*] versus [*no changes*]; and when not endowed, the affective system views the same choice as [*gain P_C*] versus [*gain $u(x)$*]. Hence, the selling price P_S and the choice price P_C are determined by $P_S + h(W, \sigma)[a_M P_S - \lambda a_x u(x)] = u(x) + h(W, \sigma)[0]$ and $P_C + h(W, \sigma)[a_M P_C] = u(x) + h(W, \sigma)[a_x u(x)]$, which generates $P_S/P_C = [1 + h(W, \sigma)\lambda\, a_x]/[1 + h(W, \sigma)\, a_x]$. Given $\lambda > 1$, not surprisingly our model yields an endowment effect ($P_S/P_C > 1$). More important, our model makes several predictions with regard to the endowment effect.

> *Endowment Effect Prediction #7 (R-7):* Any increase in $h(W, \sigma)$ will increase the magnitude of the endowment effect (increase P_S/P_C).
>
> *Endowment Effect Prediction #8 (R-8):* Any factor that increases the intensity of the affective motivation for the object will increase the magnitude of the endowment effect (increase P_S/P_C).

Because the endowment effect is driven by the affective system, willpower depletion or unrelated cognitive demands, such as cognitive load, will magnify the endowment effect. Moreover, because affective intensity for the object will magnify the impact of the affective system, it will also magnify the endowment effect. We know of no evidence for R-7. But there is support for the role of affective intensity for the object, Prediction R-8. Considerable research suggests that the endowment effect is more pronounced for outcomes such as changes in health status (see, for instance, Thaler, 1980). In one meta-analysis, Horowitz and McConnell (2002) found that, whereas the mean ratio of willingness to accept relative to willingness to pay for ordinary private goods was 2.9, this ratio was 10.1 for goods involving health and safety. While health outcomes differ from other outcomes in many ways, they are frequently associated with strong emotional reactions, and are thus more vulnerable to the effect of loss aversion and related features of the affective system.

Discussion

Taking account of the interplay between affect and deliberation helps to make sense of several important behavioral effects in the literature on decision making under risk, and it also leads to novel predictions about specific behaviors. Beyond the phenomena and predictions just outlined, the same framework could potentially shed light on and generate novel predictions concerning a variety of risk-related phenomena. For instance, the model can be used to understand the effects of temporal proximity on risk-taking. There is a great deal of evidence that temporal proximity is an important determinant of fear responses. As the prospect of an uncertain aversive event approaches in time, fear tends to increase even when cognitive assessments of the probability or likely severity of the event remain constant (Loewenstein, 1987; Roth et al., 1996). Similarly, after the moment of peak risk recedes into the past (e.g., after a near-accident), fear lingers for some period, but dissipates over time. Evidence that temporal proximity can influence risk behaviors comes from studies wherein people initially agree to do various embarrassing activities in exchange for payment, but then closer to the time when the activity has to be performed, change their minds (Van Boven et al., 2005). Moreover, consistent with changes in the affective state of fear being the cause, subjects who were shown a film clip designed to induce fear (from Kubrick's "The Shining") right before they made their initial decision were much less likely to choose to perform, and hence less likely to change their minds when the so-called "moment of truth" arrived.

Social Preferences

Humans experience a wide range of social emotions, from powerful empathic responses, such as sympathy and sadness, to more negative emotions, such as anger and envy. To give a flavor for how our two-system perspective can be applied to social preferences, in this section we apply our model to one specific social motive—altruism—and its associated affect—sympathy. The perspective we suggest is that the deliberative system has a stable concern for others driven by moral and ethical principles for

how one ought to behave. The affective system, in contrast, is driven toward anything between pure self-interest and extreme altruism depending on the degree of sympathy that is triggered.[8]

Suppose that each option x in the choice set X is a pair of payoffs $x = (x_S, x_O)$, where x_S is a payoff for oneself and x_O is a payoff for another person. The deliberative system puts some stable weight ϕ on the other person's payoff, and so its utility function is $U(x) = x_S + \phi x_O$. The affective system, in contrast, puts a variable weight on the other person's payoff that depends on the degree of sympathy that the person currently feels toward the other. Because the degree of sympathy is naturally interpreted as the intensity of affect, the affective system's motivational function is $M(x, a) = x_S + a x_O$.

Incorporating these functions into Equation 1, the person will choose the option x that maximizes

$$V(x) = [x_s + \phi x_o] + h(W, \sigma)[x_s + a x_o]. \quad (4)$$

One motivation for the assumptions in this section comes from studies of other-regarding behavior in animals, which, again, we take as evidence for what drives the affective system. Animals, including monkeys and rats, can be powerfully moved by the plight of others (for an overview, see Preston & de Waal, 2002). At the same time, other-regarding behavior is not always observed in animals. Masserman, Wechkin, and Terris (1964), for instance, found that prosocial behavior in primates (aiding another animal that was being subjected to electric shocks) was more likely in animals that had experienced shock themselves, was enhanced by familiarity with the shocked individual, and was nonexistent when it was a different species of animal. Perhaps stretching the terminology used in this article we can interpret these findings as a decrease in proximity leading to reduced concern for others.

Research by Joshua Greene and colleagues (Greene et al., 2001, 2004) provides neural evidence on our perspective. They compared how people react to "personal" moral judgments, which involve doing personal harm to another— for example, pushing a person in front of a trolley to stop it from hitting five other people— with how they react to "impersonal" moral judgments—for example, flicking a switch so that the trolley turns to another track and only

hits one person instead of five. They proposed that such judgments are made using a combination of cognitive processes that argue for utilitarian judgments and emotional processes that deter one from doing direct harm to others. Consistent with this view, they found that affective regions of the brain, such as areas of the temporal sulcus and posterior cingulate, are activated more for personal moral judgments than for impersonal moral judgments, whereas deliberative areas, such as the dorsolateral prefrontal cortex, are activated more in the opposite setting (and it has long been known that people are less likely to make the utilitarian judgment for the personal moral dilemma).[9] In the same vein, more recent research has shown that patients with brain damage to affective regions, such as the ventromedial prefrontal cortex, are more likely to make utilitarian, impersonal moral judgments, even in highly personal settings (Koenigs et al., 2007).

Predictions

Maximizing Equation 4 is equivalent to maximizing $\tilde{V}(x) = x_S + \tilde{\phi}(a)x_O$, where $\tilde{\phi}(a) = [\phi + h(W, \sigma)a]/[1 + h(W, \sigma)]$. Hence, the person's choice will reflect an effective concern for others that is a weighted average of the deliberative concern ϕ and the affective concern a. Moreover, the affective system can push behavior toward more or less concern for others relative to the deliberative optimum. In situations where there is very little sympathy triggered in the affective system, the affective system will push behavior closer to pure self-interest—as reflected by $a < \phi$ implying $\tilde{\phi}(a) < \phi$. In contrast, in situations where there are very high levels of sympathy triggered in the affective system, the affective system will push behavior toward more altruism—as reflected by $a > \phi$ implying $\tilde{\phi}(a) > \phi$.

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[8] Note that in general, sympathy and altruism are not identical: Altruism may stem from sympathy, if behavior is controlled by the affective system, or it may stem from moral principles, if behavior is controlled by the deliberative system.

[9] Though note that Greene et al. (2004) suggest that the relationship between cognition and emotion may not be this simple; that is, certain limbic areas, such as the anterior cingulate cortex, may also be involved in detecting conflict between emotion and cognition, and in recruiting prefrontal cortex control of emotional regions to resolve this conflict.

To generate testable predictions, we apply the general predictions of our model.

Social Choice Prediction #1 (S-1): An increase in $h(W, \sigma)$ will increase $\tilde{\phi}(a)$ when affective intensity is high $(a > \phi)$ and decrease $\tilde{\phi}(a)$ when affective intensity is low $(a < \phi)$.

Social Choice Prediction #2 (S-2): Any factor that increases the intensity of the affective motivation will increase $\tilde{\phi}(a)$.

S-1 reflects that the effects of willpower depletion or unrelated cognitive demands, such as cognitive load, depend on the degree of sympathy experienced. Specifically, when a person experiences little or no sympathy our model predicts that willpower depletion or cognitive load should reduce the likelihood of an altruistic act. In contrast, when a person experiences high sympathy our model predicts that willpower depletion or cognitive load should increase the likelihood of an altruistic act.

Gailliot et al. (2007) provide support for the effects of willpower depletion when sympathy is low. Specifically, in a task involving hypothetical questions about charitable giving and helping behavior toward strangers—both arguably low-sympathy situations—they found that subjects with higher willpower depletion were indeed less altruistic. There is also evidence on the effects of affective intensity (S-2). Perhaps the most direct evidence comes from a study by Batson et al. (1995) on empathy-induced altruism. They manipulated subjects' empathy toward a target individual by having them read a short description of that individual's need while taking an objective perspective (low empathy) or while trying to imagine how that individual feels (high empathy). They then gave subjects the opportunity to help the target despite the fact that doing so would violate some moral principle of justice such as random allocations or allocation based on need. Consistent with S-2, they found that subjects in the high-empathy treatment were much more likely to help the target individual.

S-2 also helps to explain why people treat statistical deaths differently than identifiable ones, since foreknowledge of who will die (or which group deaths will come from) creates a more vivid—and evocative—image of the consequences (see Schelling, 1968; Bohnet & Frey, 1999; Slovic, 2007, Small & Loewenstein, 2003, for an experimental demonstration).

A recent study by Small et al. (2007) provides further support for our perspective on the role of identifiability. Small et al. provided subjects with the opportunity to donate to a charity, and manipulated whether subjects were shown an identifiable victim (a picture and a description of a little girl) or a statistical victim (factual information about the overall problem). They also manipulated the extent to which people were primed to think more deliberatively. They found that deliberative thought decreased donations to the identifiable victim, but did not affect donations to the statistical victim. Under the plausible assumption that the affective system plays a major role in donations to the identifiable victim and but not in donations to the statistical victim, these results are what our model (Prediction S-2) predicts.

While we have focused our analysis solely on the simple social motive of altruism, researchers have discussed other social motives as well. For instance, there is a large literature that focuses on people's concerns for relative payoffs (Bolton & Ockenfels, 2000; Fehr & Schmidt, 1999; Loewenstein et al., 1989; Messick & Sentis, 1985). In principle, our model could be applied to these concerns as well; however, because both concerns would seem to have both a deliberative and an affective component, it is not entirely obvious what to assume about the motives of the two systems. Similarly, another area our approach could be applied to is game theoretic decision making. Groups of decision makers are frequently able to avoid rational, but inefficient, outcomes, such as defection in prisoner's dilemma type games. While there are many reasons why decision makers cooperate in this manner, affective impulses, that are especially pronounced with close others, may play an important role in explaining this behavior.

Discussion

There is a great deal of evidence that people's decisions are influenced by both affective and deliberative processes. Whereas standard consequentialist models focus, for the most part, on deliberative processes, our main contribution in this article has been to develop a formal model to incorporate affective processes. In particular, we have modeled the impact of affective processes using a motivation function that is myopic, that displays loss aversion and is insensitive

to probabilities, and that is influenced by sympathy and empathy concerns. The impact of this motivation function on behavior is increasing in the affective intensity of the stimuli in consideration, increasing in unrelated cognitive demands, such as cognitive load, and decreasing in the willpower possessed by the decision maker. We have shown that our model can explain a range of psychological, behavioral and neuroscientific results regarding intertemporal, risky and interpersonal decision making, and generates some new predictions that have not yet been tested.

Ours is not the first dual-process model of decision making. Metcalfe and Mischel's (1999) hot/cool model and Fazio and Towles-Schwen's (1999) MODE model, for example, propose that behavior is the product of two systems: one emotional and the other cognitive. Metcalfe and Mischel use their model to understand the effect of willpower, and Fazio and Towles-Schwen apply their model to attitude formation and other aspects of social judgment. Our model differs from these two important and influential approaches in its focus on preferential choice and its ability to make quantitative predictions in this domain.

These properties make our model similar to formal dual-process theories of intertemporal choice in economics (Benhabib & Bisin, 2005; Bernheim & Rangel, 2004; Fudenberg & Levine, 2006; Shefrin & Thaler, 1988; Thaler & Shefrin, 1981). Indeed some of our assumptions—such as those of affective myopia—resemble those made by these approaches, and many of the insights presented by these approaches hold for our model as well. What is unique about our model is its ability to make predictions across a number of different domains, including both intertemporal and risky choice, as well as social choice. These predictions rely on a small set of fundamental principles—such as the sensitivity of emotion to proximity and vividness, the consequentialist nature of deliberation, and the role of willpower in resolving the conflict between these two systems—principles that are firmly grounded in psychology and neuroscience. Our model can thus be seen as generalizing these existing approaches, and subsequently extending the descriptive and conceptual scope of dual process theory for preferential choice.

Our model also resembles a prior dual-process theory in psychology. Particularly Mukherjee (2010) builds upon an early version of our model (Loewenstein & O'Donoghue, 2004) to study risk preferences in detail. As in Loewenstein & O'Donoghue (2004), Mukherjee assumes a deliberative and an affective system interact to determine behavior, where each has its own objective function, and behavior is determined by a weighted sum of the two objective functions. Also as in Loewenstein & O'Donoghue (2004), for the domain of risk preferences, Mukherjee assumes that the deliberative system focuses on expected value whereas the affective system is influenced by loss aversion and a complete insensitivity to probabilities (Mukherjee further assumes that the affective system is also influenced by diminishing sensitivity). Mukherjee then investigates the implications of this model for a number of well-known decision problems that have emerged in the prospect theory literature: violations of stochastic dominance, the nature of risk attitudes, ambiguity aversion, the common consequence effect, the common ratio effect, and the isolation effect. However, Mukherjee's analysis does not focus on the impact of willpower, cognitive load, or affective intensity, which is a primary focus of our article. Moreover, when we apply our model to risk preferences, we focus on implications for a completely different set of risk contexts—specifically, for four frequently studied experimental paradigms: eliciting monetary certainty equivalents for monetary gambles, eliciting monetary certainty equivalents for nonmonetary gambles, decisions whether to accept or reject mixed (gain-loss) gambles, and the endowment effect.

There are a number of directions in which to further expand upon our framework. Perhaps the most important is to more fully explore the dynamics of willpower. We have provided an outline of how willpower can change during the time course of the decision process, leading to switches midway through choice; however, there are even more nuanced willpower dynamics. For instance, some, albeit preliminary, studies have found support for the idea that, in addition to being depleted in the short-term by exertion, willpower, like a muscle, may become strengthened in the long-term through repeated use (Muraven et al., 1999). More importantly, people's behavior might also reflect their at-

tempts to manage their use of willpower. There is in fact experimental evidence, in a version of the Baumeister paradigm, that people do have some awareness of the dynamic properties of willpower and take these into account in a strategic fashion (Muraven, 1998).

A second direction in which to expand our framework is to study people's assessments of their own behaviors. Because such assessments are an inherently cognitive task, they will naturally tend to exaggerate the role played by deliberation. In effect, one could say that the deliberative self egocentrically views itself as in control and commensurately underestimates the influence of affect (see Wegner & Wheatley, 1999). This failure to appreciate the role of affect in behavior can have a negative impact on efforts at self-control.

An implication of failing to appreciate the role of affect is that people will exaggerate the importance of willpower as a determinant of self-control. People who are thin often believe they are thin because of willpower, and that those who are less fortunate exhibit a lack of willpower. However, it is far more likely that those who are thin are blessed (at least in times of plentiful food) with a high metabolism or a well-functioning ventromedial hypothalamus (which regulates hunger and satiation). Indeed, obese people who go to the extraordinary length of stapling their stomach to lose weight often report that they have a sudden experience of "willpower" despite the obvious fact that stapling one's stomach affects hunger rather than willpower (Gawande, 2001). It is easy and natural for those who lack drives and impulses for drugs, food, and sex to condemn, and hence to be excessively judgmental and punitive, toward those who are subject to them—to assume that these behaviors result from a generalized character deficit, a deficiency in willpower. Similarly, the rich, who are not confronted with the constant task of reigning in their desires, are likely to judge the short-sighted behaviors of the poor too harshly. There is in fact recent evidence that people who are in elevated affective states tend to have a much more acute appreciation of the power of drives and the limitations of self-control than those who are affectively neutral states (Nordgren et al., 2007).

A third direction in which to expand our framework is to take it to specific domains in order to develop more detailed model specifications and quantitative predictions. Mathematical models have two types of goals: (a) developing precise qualitative predictions, and (b) developing precise quantitative predictions. Our analysis in this article has focused exclusively on the former—for example, deriving precise qualitative predictions for the directional impact of cognitive load, willpower depletion, and affective intensity on various behavioral outcomes. As such, we have imposed relatively little general structure on the deliberative utility function U, the affective motivational function M, and the cost function h for mobilizing willpower. But if researchers take our framework to specific domains, it will be natural to impose—or better yet estimate—a more fully specified model, and to use that model to generate more quantitative predictions. Such a quantitative analysis would also help in comparing our model with the nested baseline rational model (which would involve only the deliberative utility function, U).

After decades of domination by a cognitive perspective, in recent decades affect has come to the fore as a topic of great interest among psychologists. In this article, we attempt to integrate many of the findings from research conducted by psychologists and decision researchers interested in affect by proposing a formal model of interactions between affect and deliberation that can both explain existing findings and also generates testable but as yet untested predictions. If further testing substantiates these predictions, and hence the model, this could constitute the first step toward a formal theoretical perspective that integrates two major sides of human judgment and behavior.

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