

Temporal self-regulation theory: A model for individual health behavior

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Abstract

Human behavior often seems “maladaptive”, “self-defeating”, or “dysfunctional” to the observer. Upon closer examination, the rationality of human behavior largely depends on the temporal frame adopted; behaviors judged to be maladaptive in the long-run are usually driven by a strongly favorable balance of immediate costs and benefits. That is, many “maladaptive” behaviors are associated with substantial long-term costs and few (if any) long-term benefits; however, these same behaviors are frequently associated with many benefits and few costs for the individual at the time of action. In contrast, many avoided behaviors that seem “adaptive” to the outside observer, are in fact associated with substantial costs (and few benefits) at the time of action, leading to the perplexing but common state of affairs where individuals know “what is good for them”, but do not do it. We present a new theoretical framework—Temporal Self-Regulation Theory—as a way of understanding human behavior in general, and those special instances of seemingly “self-defeating” behavior that have important implications for physical health. This theoretical framework incorporates thinking about temporal aspects of behavioral contingencies and the biological roots of self-regulation to make sense of human behavioral patterns that seem to represent, on the surface, significant deviations from rationality.

Keywords: *Health behavior, self-regulation, executive function, time perspective, theory*

Introduction

Human behavior deviates significantly from classical notions of rationality (Dawes, 1988; Kahneman, 2003; Tversky & Kahneman, 1974, 1981, 1986).

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People often do things that they perceive to be good for them in the here-and-now, despite the potential for long-term harm (Fong & Hall, 2003; Strathman, Gleicher, Boninger, & Edwards, 1994; Zimbardo & Boyd, 1999); they refrain from doing “the right thing” even under circumstances where they know what “the right thing” is; they are tempted by rewards that are immediately available to the exclusion of greater rewards later in time (Loewenstein & Thaler, 1989; Mischel, Shoda, & Rodriguez, 1989). Indeed, self-defeating behavior is so ubiquitous that rationality in judgment and decision-making seems to be comparatively rare, and nowhere is this more apparent than in the domain of health behavior.

Despite widespread knowledge about the risks of unprotected sexual intercourse, smoking, and substance abuse, rates of these behaviors are still unacceptably high in most industrialized nations (World Health Organization, 2002). Meanwhile, health protective behaviors (e.g., regular physical activity, healthy dietary choice) are seldom performed with enough consistency to derive the potential health benefits, leaving large segments of the population vulnerable to the development of serious chronic illnesses later in life (Mokdad et al., 2001; Rose, 1994; Tremblay, Katzmarzyk & Willms, 2002). In the words of Dr. Gro Harlem Brundtland, former Director-General of the World Health Organization, “The world is living dangerously – either because it has little choice, or because it is making the wrong choices” (World Health Organization, 2002). Indeed, we will argue that our “living dangerously” arises from both of these factors: (1) the palpable seduction of “wrong choices”; and (2) the constraining of healthy choices by our own environmental structure, our biological predispositions, and our natural cognitive proclivities. Importantly, we will also argue that many—though not all—of these influences can be overcome.

Explaining individual health behavior

Numerous theoretical frameworks have been offered to explain health behavior, many of which are based on the rational approach initially described by von Neumann and Morganstern (1947), and refined in the form of the Subjective Expected Utility Model (SEU; Savage, 1954). The Theory of Reasoned Action (TRA; Fishbein, 1967; Fishbein & Ajzen, 1975) and its extension, the Theory of Planned Behavior (TPB; Ajzen & Madden, 1986) are among the most highly cited of SEU’s more modern extensions. Both TRA and TPB posit that behavior is most proximally determined by intentions to perform the behavior. Intentions, in turn, are determined by individuals’ beliefs about the extent to which significant others would approve of behavioral performance, and valence of attitude toward the behavior. The TPB adds that behavior and behavioral intention are also predictable by knowing about perceptions of controllability of the behavior. Each of these constructs – subjective norm, attitude, and perceived behavioral control – are, in turn, determined by beliefs about the anticipated outcomes of behavioral performance.

How well do TRA and TPB predict behavior? The evidence from correlational studies suggests that both do a reasonable job of predicting variance in behavior

in general, and health behavior in particular (Godin & Kok, 1996; Sheeran, 2002; Sutton, 1998), with some controversy over the extent to which perceived behavioral control adds incremental predictability over intention alone (Armitage & Conner, 2001; Terry & O'Leary, 1995). How well do TRA and TPB *explain* behavior? For this question, the answer is less clear. In a recent meta-analysis, Webb and Sheeran (2006) reviewed experimental studies examining the intention-behavior link and found that medium-to-large increases in behavioral intention induce only small-to-medium changes in behavior. As such, it appears that TRA and TBP do a better job of predicting behavior than explaining it *per se*. This is not inconsistent, however, with the original intention of these models.

The Webb and Sheeran meta-analysis also raises important questions about the complexity of the intention-behavior relationship. Is the relation between intention and behavior both uniform and consistent? It would appear that the answer to this question is "no". In their meta-analysis, Webb and Sheeran identified a number of moderators of the intention-behavior link, including habit control, perceived/actual controllability of the behavior, and social context. Specifically, causal intention-behavior relations were stronger when the behavior was more controllable (objectively and subjectively), when it was under weaker habitual control, and in the presence of a supportive social context.

Most individuals have a strong intuitive recognition that change is difficult and that initial intentions are not perfectly translatable into sustained change over the long run. Indeed, empirical literature on consistency in exercise adherence (Dishman, 1991), dietary adherence (Dansinger, Gleason, Griffith, Selker, & Schaefer, 2004), medication adherence (Meichenbaum & Turk, 1987), and smoking cessation (Curry & McBride, 1994) largely supports this subjective impression. A shift toward self-regulatory models of health behavior in the research literature suggests that the scientific community also appreciates the dynamic nature of health behavior, and the changeability of intention-behavior relations over time (Baumeister & Vohs, 2004; Cameron & Leventhal, 2003; Norman & Abraham, 2000; Schwarzer, 2001). Most such models share the conviction that health behavior is not an exclusively intention-driven phenomenon, an acknowledgement that was part of the impetus for the original revision of the TRA to include a perceived control dimension (Ajzen & Madden, 1986).

Why is it that intentions are imperfectly associated with health behavior? There are at least three possibilities: (1) intentions are not perfectly translatable into behavior; (2) intentions are not accurately reported in the first place; or (3) intentions sometimes change immediately prior to the opportunity for behavioral performance. The risk of circularity is high in the case of options 2 and 3. Intention change and/or inaccurate reporting could always be offered as *post hoc* explanations in the absence of actual measurement of acute intention. Nonetheless, this issue cuts to the core of the intentions construct: what are intentions anyway? Some have suggested that the intentions construct should be assessed as close in time to behavioral performance as possible to ensure optimal prediction of behavior (e.g., in an extreme example, a person's intention to smoke should be assessed just prior to reaching for the pack of cigarettes). From a predictive

standpoint this is useful in a raw empirical sense, but perhaps less so from a theoretical explanatory perspective. For example, are acute pre-behavior intentions causal forces or just a form of (epiphenomenal) anticipatory cognition? In order to avoid circularity with respect to the intentions construct, it must be *a priori*, and in this form it has been shown to be only moderately related to behavior from a causal standpoint. From this perspective, intention-behavior relations are imperfect for most health behaviors, and we present evidence to suggest that self-regulatory factors explain at least some of this discrepancy.

There are other reasons to prefer self-regulatory models of health behavior. For example, it is possible that behaviors wax and wane over time and that different factors predict behavior at different phases of the change process (Prochaska, DiClemente, & Norcross, 1992; Rothman, 2000). Perhaps more generally, there has been increasing recognition of the influence of temporal factors on the decision-making process itself (Loewenstein & Elster, 1992; Loewenstein & Thaler, 1989; Loewenstein, Read, & Baumeister, 2003). Might these temporal factors be especially important with respect to the phenomenology of health behavior? This is the question that we turn to next.

Temporal dimensions of health behavior

Contrary to common belief, in all but the poorest countries today, the greatest health burden is due to chronic diseases, not infectious diseases (World Health Organization, 2005). Many have attributed this shift in focus away from infectious disease to the success of modern medicine in treating acute illness. Others emphasize the role of improved living conditions and hygienic practices which have reduced the threat of many infectious diseases (e.g., cholera and smallpox; Rose, 1994). Regardless of the cause, the net result of the decline of infectious disease around the industrialized world has been an increase in average life expectancy. As human beings are living longer now than ever before, slowly progressing chronic disease processes, such as coronary heart disease and many forms of cancer, have become the primary limiting factors for the human lifespan. It is now widely known that most of these chronic diseases could be prevented through the alteration of just a few behavioral patterns: poor diet, smoking, lack of exercise, substance abuse, and maladaptive responses to stress (LaLonde Commission of Canada, 1974; U.S. Surgeon General, 1979; World Health Organization, 2002).

Prevention of chronic diseases requires action many years, or even decades, before any symptoms of the disease develop. It is only through the recognition that one's current actions are linked to these later outcomes (presence *vs.* absence of disease) that it is possible to regulate one's own behavior in the appropriate directions. Most health protective behaviors involve inconvenience, or even discomfort and embarrassment at the time of performance (Fong & Hall, 2003). Adding to the negative attributes of such health behaviors is the fact that many have few immediate benefits. The majority of the benefits to be gained are far into the future and, therefore, the most compelling reason why individuals might want

to perform health protective behaviors would be in the interests of these longer-term considerations.

Physical activity, for example, is associated with many health, physical appearance, and psychological benefits. None of these, however, are manifest at the time that one makes the choice to get up several hours earlier than usual to get oneself to the gym before going to work in the morning. Instead, what is most salient at this crucial moment of decision-making is the time cost and inconvenience associated with exercising. The long-term positive contingencies that so powerfully motivated one to make a New Year's resolution "to finally get in shape this year", are only faint shadows in the face of these strongly negative immediate contingencies for making the healthy choice. This example demonstrates how immediate contingencies for health protective behaviors can potentially de-motivate behavioral performance, even under conditions of strong (and publicly espoused) intentions to the contrary.

Smoking behavior provides an example of how the same temporal considerations come into play for health risk behaviors. For the habitual smoker, lighting up the next cigarette is potentially associated with a variety of immediate benefits, including feelings of well-being, avoidance of withdrawal symptoms, and improved concentration. Depending on the composition of one's social network, lighting up might also win acceptance from one's peers, and improve one's sense of self-worth through feelings of belonging within the group. In contrast to these immediate benefits, there are few if any immediate costs.¹ In the long-term, however, the balance of costs and benefits is reversed. Although there are presumably few long-term benefits associated with smoking, the long-term health consequences are devastating: approximately half of all chronic smokers will die prematurely, at an average loss of life expectancy of 10 years (Doll, Peto, Boreham, & Sutherland, 2004). Physical appearance costs also accrue gradually over time, including premature aging of the skin, tooth enamel stains, and other unsavory dental conditions (Aizen & Gilhar, 2001; Grady & Ernster, 1992; Koh, Kang, Sung, & Hyung, 2002; Locker, 1992; Onder, Oztas, & Arnavut, 2002; Taybos, 2003).

Does the evidence support the assumption that temporal dispersion of costs and benefits of health behavior exists on the level of individual perception? In a recent study (Hall, 2007), we examined the perceived temporal proximity of hypothetical costs and benefits associated with two health protective behaviors: exercise and healthy dietary choice. From focus groups, expert consultations, and surveys of existing measures of behavioral beliefs, we compiled an exhaustive list of potential costs (e.g., "inconvenience") and benefits (e.g., "improved appearance") of each behavior, and then asked a separate sample of healthy adult participants to indicate when they believed that each cost and benefit would become salient to them if they were to experience it, using the temporal proximity measure reproduced in Table I. Figures 1 and 2 show perceived temporal proximity of costs *vs.* benefits of each behavior, respectively. As is clear from these graphs, participants perceived exercise behavior to be associated with costs leading up to the point of decision (corresponding with point 4 on the x-axis), and

Table I. Temporal proximity measure for exercise and dietary behavior.

If you were to experience [COST/BENEFIT] from exercise, WHEN do you think that you would notice it? (check the box that corresponds with your answer)

- 1. When I am thinking about whether or not to exercise
- 2. When I make the decision to exercise
- 3. While I am getting ready to exercise
- 4. While I am exercising
- 5. After exercising once
- 6. After exercising regularly for a week
- 7. After exercising regularly for a month
- 8. After exercising regularly for a year
- 9. After exercising regularly for several years
- 10. After exercising regularly for several decades

If you were to experience [COST/BENEFIT] from making a healthy dietary choice, WHEN do you think that you would notice it? (check the box that corresponds with your answer)

- 1. When I am thinking about whether or not to make a healthy food choice
- 2. When I make the decision to make a healthy food choice
- 3. While I am getting ready to make a healthy food choice
- 4. While I am making a healthy food choice
- 5. After making a healthy food choice once
- 6. After making healthy food choices regularly for a week
- 7. After making healthy food choices regularly for a month
- 8. After making healthy food choices regularly for a year
- 9. After making healthy food choices regularly for several years
- 10. After making healthy food choices regularly for several decades

benefits becoming salient the equivalent of several hundred hours later, after repeated performance (corresponding with point 6 or 7 on the x-axis). The graph for diet also illustrates the significant temporal disjunction for costs and benefits, with a somewhat more even distribution of costs over time. For both health protective behaviors, mean differences between perceived proximity of costs and benefits are very large and are highly statistically significant, confirming that health protective behaviors are viewed as involving many proximal costs and only

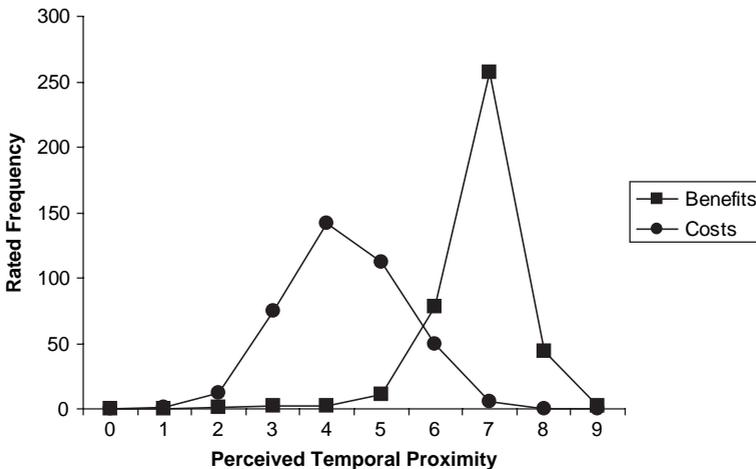


Figure 1. Temporal distribution of perceived contingencies for exercise behavior.

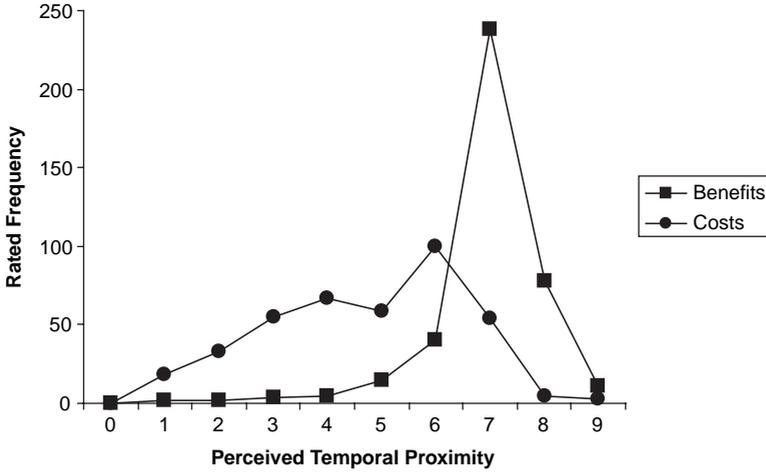


Figure 2. Temporal distribution of perceived contingencies for healthy dietary choice.

very distal benefits. In the case of smoking and drinking behavior, temporal dispersion of costs and benefits for substance use are opposite (though not perfectly opposite) those for health protective behaviors, with benefits being perceived as substantially more proximal than costs (see Figures 3 and 4; McEown & Hall, 2005).

The same temporal issues figure prominently in virtually all health behaviors, including adhering to a medical regimen, using condoms, and engaging in the physically taxing (but ultimately beneficial) process of physical rehabilitation following injury. Each of these behaviors is associated with a characteristic set of contingencies whose valence changes dramatically depending on the temporal frame; each is associated with many costs in the short-term (e.g., inconvenience, discomfort, loss of pleasure), and few benefits. In the long-term, many benefits emerge (e.g., longer life span, improved functional status, decreased risk for disease), and costs are minimal in comparison. Attention to long-term contingencies, then, should motivate the performance of health protective behaviors, while

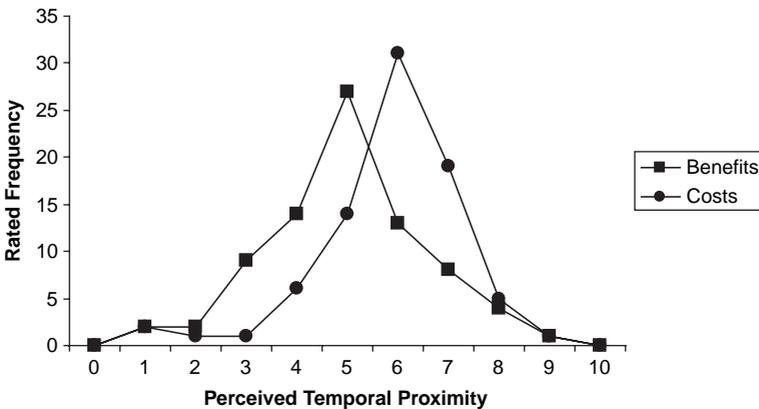


Figure 3. Temporal distribution of perceived contingencies for smoking behavior.

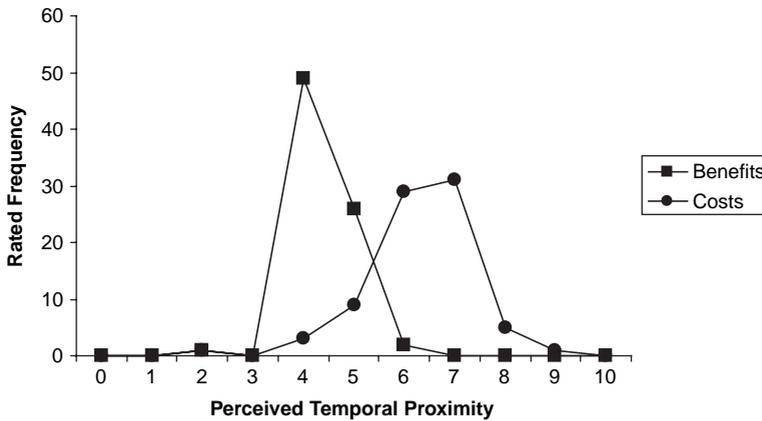


Figure 4. Temporal distribution of perceived contingencies for drinking behavior.

attention to short-term contingencies should de-motivate performance of health protective behaviors. Thus, consistent performance of health protective behaviors and avoidance of health risk behaviors almost always requires active and effortful self-regulation in accordance with non-immediate behavioral contingencies.

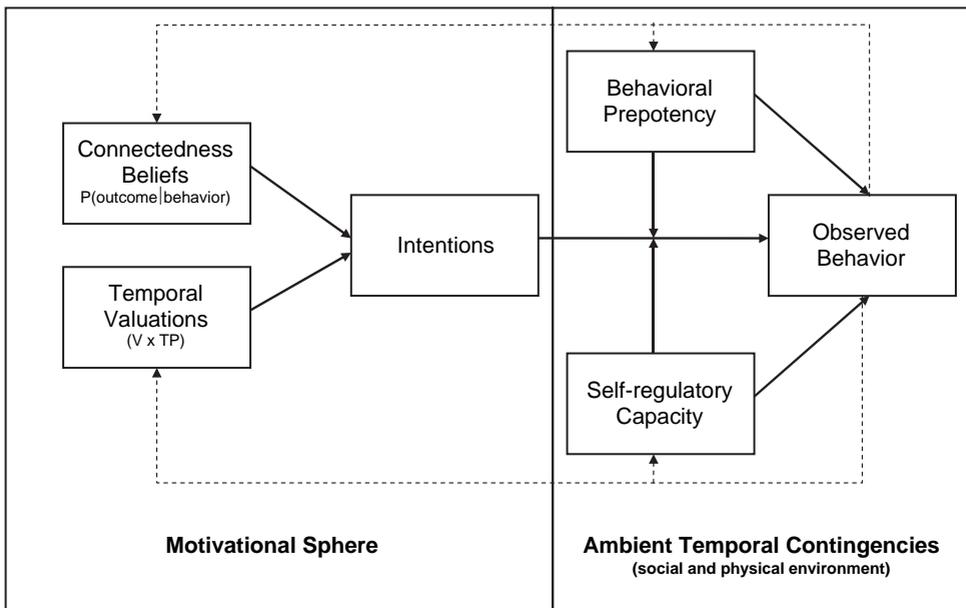
Despite the clear relevance of temporal contingencies for understanding health behavior, only recently have theoretical frameworks begun to take them into account (e.g., Trope & Liberman, 2003). As we will discuss, most traditional theories of health behavior include expectancy-value components, and several include a clear role for behavioral intention. However, none invoke the concept of dispersed costs and benefits over time, or biologically imbued capacity to regulate one's own behavior in accordance with non-immediate contingencies, both of which should be important for understanding intra- and inter-individual variability in health behavior performance over time. Finally, the notion of behavioral prepotency—defined as the likelihood of performance of a given behavior as a function of habit, cues to action, or internal drive states—has been clearly identified as important (Baumeister & Heatherton, 1996; Ouellette & Wood, 1998) but has yet to be modeled explicitly within a general theory of health behavior. In short, despite their success and popularity, many existing social cognitive models of health behavior may be missing crucial variables, and have been under-informed by research in behavioral economics and cognitive neuroscience. In the sections that follow, we present a new theoretical account of health behavior that incorporates temporal dimensions of behavioral contingencies, as well as state and dispositional moderators of the intention-behavior relationship, in the form of biologically imbued self-regulatory capacity and behavioral prepotency.

Temporal self-regulation theory

There is ample evidence from the behavioral economic and social psychological literature to suggest that hyper-responsivity to immediate contingencies is pervasive and exerts a “main effect” on human behavior (Loewenstein et al.,

2003). A significant body of literature also supports the contention that important individual differences exist therein (Fong & Hall, 2003; Mischel et al., 1989; Strathman et al., 1994; Zimbardo & Boyd, 1999). Both of these phenomena—the universal tendency toward hyper-responsivity to immediate contingencies, and individual differences in time perspective (i.e., the tendency to behave in accordance with short- *vs.* long-range contingencies; Fong & Hall, 2003)—can be explained by Temporal Self-Regulation Theory (TST; Hall, 2001; see Figure 5).

According to TST, the capacity to engage in behavior in accordance with long-range interests arises from a complex combination of biological, cognitive, and social factors. Specifically, biologically imbued self-regulatory capacity (a person construct consisting of executive system functioning, and physiological energy), social cognitive variables, such as beliefs about the connectedness of present behavior to later outcomes (i.e., “connectedness beliefs”), and values attached to temporally dispersed outcomes (i.e., “temporal valuations”), are all crucial ingredients in understanding future-oriented behavior. Consistent with other theories of human behavior, TST holds that motivation to engage in any behavior is primarily a function of the perceived likelihood of expected outcomes and values attached to them. As such, a special variant of the expectancy-value framework is sufficient to explain the motivational sphere of influences on intentional behavior. Two factors, however, can moderate the strength of the intention-behavior link: (1) behavioral prepotency; and (2) self-regulatory capacity. Behavioral prepotency is defined as a quantifiable value reflecting



Note: Arrows between Behavioral Prepotency and Self-regulatory Capacity to the Intentions-Behavior arrow implies moderation; V = value; TP = perceived temporal proximity. Broken arrows denote weaker (i.e., secondary) hypothesized effects.

Figure 5. A schematic representation of Temporal Self-Regulation Theory (TST v1).

frequency of past performance and/or the presence of cues to action in the environment. Self-regulatory capacity, on the other hand, can be defined as any state- or trait-like factor that affects an individual's capacity to effortfully regulate their own behavior (e.g., executive function, energy level). The influence of these moderating factors is expected to increase as the temporal disjunction (immediate *vs.* non-immediate) in the valence (positive *vs.* negative) of behavioral contingencies increases. As such, the ambient temporal contingencies (i.e., the balance of immediate and non-immediate contingencies) associated with a specific behavior in a particular environmental context can make the opposing forces of behavioral prepotency and self-regulatory capacity more or less influential on actual behavior, by slanting the default behavior toward performance or non-performance.

In addition to their moderating effects on the intention-behavior link, both behavioral prepotency and self-regulatory capacity should have direct effects on behavior. For example, the frequency of past performance and the presence of eliciting cues in the environment make a behavior more likely to occur even in the absence of intention. Likewise, low self-regulatory capacity can effectively render non-deliberated behavior more or less likely depending on the immediate contingencies supplied by the environment. In a hypothetical scenario, wherein there is no disjunction between when costs and benefits of a behavior fall in time (i.e., they are both relatively immediate), the moderating potential of self-regulatory capacity and behavioral prepotency would approach zero, thus allowing a reversion to a simple expectancy-value explanation of behavior. In an alternative scenario when costs are, on balance, more proximal than benefits (or the reverse), moderating factors become increasingly influential as the temporal disjunction between costs and benefits becomes more pronounced. This latter scenario is the more common one when health behaviors are concerned.

We discuss the concepts of behavioral prepotency and self-regulatory capacity in more detail in the sections that follow.

Behavioral prepotency

A *prepotent response* can be defined as “any reflex or response that takes precedence over any other potential reflex or response that an organism might make” (Reber, 1995; see also Barkley, 1997). In humans, as well as in lower animals, the degree of prepotency associated with a given behavior can be dictated directly by: (1) internal biological drives like hunger, thirst and reproduction (Hull, 1943); (2) salient environmental cues (e.g., Steele & Josephs, 1990); or (3) past behavior (e.g., Ouellette & Wood, 1998). The capacity to suspend prepotent responses is a necessary precondition for future-oriented behavior, and is made possible by the operation of the executive system (Norman & Shallice, 1986; Fuster, 1989, 1999).

The role of the executive system in suspension of prepotent responses has been studied extensively in the laboratory, usually with reference to discrete behaviors that are easily quantifiable (e.g., button pressing, card sorting, or other discrete

choice making tasks). However, prepotent responses are ubiquitous in everyday life outside the laboratory and can take a variety of other forms, some of which are driven by biological needs and some of which are driven by social and/or affective influences. For example, under conditions of extreme food deprivation, most of us are inclined to eat a meal put in front of us; when entering a room where others are standing, one is likely to stand as well; a habitual smoker who encounters a stressful situation at work might be strongly inclined to light up a cigarette in response, especially if doing so has garnered reinforcement in the past. Unless these “default” behavioral tendencies are resisted in an effortful manner, they are likely to occur consistently in like situations or circumstances, sometimes without the individual’s full awareness that they are being performed at all. This is potentially true for discrete behavioral choices, social behaviors, and affect regulation efforts.

Past behavior—regardless of its type—is one of the strongest predictors of future behavior, sometimes exceeding the predictive power of behavioral intention and other well established social-cognitive constructs (Norman & Smith, 1995; Ouellette & Wood, 1998; Verplanken & Orbell, 2003). Indeed this is not surprising given that many behaviors and behavioral scripts (even complex ones) become so highly routinized that they are not thought about, but rather elicited “automatically” from environmental cues with minimal influences even on attentional resources (Bargh, 1990; Posner & Snyder, 1975; Shiffrin & Schneider, 1977). This is problematic for theories that posit that the final common pathway to behavior is through intention (or any other social-cognitive construct, for that matter).

A significant challenge to existing social-cognitive models of health behavior is the fact that they do not have a theoretical justification for the inclusion of prior behavior, notwithstanding *post hoc* efforts to simply add it to the model. In TST, however, past behavior has a very explicit role: it represents an objective operationalization of a prepotent response. Habitual behavior driven by stable eliciting cues is one—but not the only—variant of prepotent response. TST would predict that past behavior should be a direct and independent determinant of future behavior unmediated by other social cognitive variables and, moreover, that past behavior should moderate the relationship between intention and future behavior (Sheeran & Abraham, 2003; Triandis, 1980). This is shown graphically in Figure 5 by the paths connecting behavioral prepotency directly to behavior, and an additional moderating path from behavioral prepotency to the intention-behavior path.

In a review of the role of habit and intention in guiding behavior, Ouellette and Wood (1998) argue that past behavior is strongly predictive of future behavior—especially when the behavior is well-practiced in stable contexts—because of automatic processes that guide over-learned behavior in response to environmental cues. Ajzen (2002) has criticized this perspective, suggesting that the association between context stability and consistent behavior (from past to future) does not clearly support Ouellette and Wood’s argument because: (1) there are some instances of high behavioral consistency even in the presence of

unstable context; and (2) habit strength should only operate under conditions where cues are consistent (i.e., the environment is stable). TST, however, does not rely on habit as the only explanation for the predictive power of past behavior. Habit strength is only one of *several factors* that explain stability of behavior. We propose that internal cues (not just stable external cues), specifically ones that denote activation of biological drives (i.e., sexual, hunger, survival) will reliably potentiate the same behaviors, even in environments where the observable cues are only somewhat similar. From this perspective, fully stable external cues are not required to elicit behavior directly, as would be the case with habit strength.

As an example, consider the case of an individual who has not eaten in 24 h. This person would be quite hungry, and internal hunger cues would likely be activated by a variety of *different* external cues that pertain to food. The internal cue signifying the biological drive of hunger, however, is what initiates food-seeking behavior, and would do so reliably under loosely similar circumstances (i.e., whenever the individual goes without food for 24 h, that individual would engage in food-seeking behavior in response to many diverse external cues that trigger hunger pangs). In this scenario, then, it is the internal drives that cause consistency of behavior (and drive prepotent responses), and these are carried around within the individual until cues in the environment elicit them, even in loosely related contexts (e.g., passing a food vendor on the street, noticing a sign for a fast food restaurant, opening the refrigerator). Thus, according to TST, although habit strength and consistent contextual cues are one source of behavioral consistency in similar situations, they are not the only source.

On a personal level, prepotent responses—by their very nature—can pose significant challenges to individuals who want to change their behavior in a healthy direction. Overriding them in the interest of long-term contingencies may potentially require high motivation, but also the operation of facilitating neurobiological structures.

The biological bases of self-regulatory capacity

In mammals, “executive” functions are typically localized in the frontal lobe (Nolte, 1999), with the prefrontal cortex (PFC) and the anterior cingulate cortex (ACC) especially implicated in those executive functions most relevant to behavioral self-regulation. The connections between the PFC and ACC, and their apparent functional dependence has led some to suggest that they form a self-regulatory circuit that serves to modulate “willful action” (Paus, 2001).

The prefrontal cortex. The prefrontal cortex has significant pathways to and from the parietal and temporal lobes, and is part of a large network linking the brain’s motor, perceptual, and limbic regions. Its functions include maintaining working memory, temporal tagging of existing memory structures, filtering of environmental stimuli, and co-ordination of complex behaviors (Gazzaniga, 1995; Miller, Hyman, & Cohen, 2001; Stuss & Knight, 2002). Damage to this area is associated with breakdown of goal-directed behavior, difficulty in planning action

sequences, and behavioral hyper-reactivity to environmental cues to action (L'hermitte, 1983; L'hermitte, Pillon, & Serdaru, 1986). In rats, selective lesioning of the orbitofrontal area enhanced preference for an immediate smaller reward (food pellets) over a larger delayed reward relative to controls (Mobini et al., 2002). In humans, ingestion of substances known to impair prefrontal cortex function (i.e., alcohol) results in behavioral hyper-responsivity to immediately salient cues (e.g., MacDonald, Fong, Zanna, & Martineau, 2000). Clinical conditions that involve irregular structure and/or impaired function of the prefrontal areas are characterized by impulsivity and other difficulties with behavioral self-regulation (Barkley, 1997; Barratt, 1994; Bizot et al., 1988, 1999; Cherek & Lane, 1999; Duncan, 1986; Kaehkoenen, Wilenius, Nikulin, Ollikainen, & Ilmoniemi, 2003; Mostofsky, Cooper, Kates, Denckla, & Kaufmann, 2002; Poulos et al., 1996; Spencer, Biederman, Wilens, & Faraone, 2002; Sullivan & Brake, 2003). It suffices to say that the executive system appears vitally important for inhibition of prepotent responses and facilitation of goal-directed behavior (Fuster, 1999; Gazzaniga, Ivry, & Mangun, 1998; Koechlin, Ody, & Kouneiher, 2003; Norman & Shallice, 1986; Shallice, Burgess, Schon, & Baxter, 1989).

The prefrontal cortex is also known for its role in working memory (Gazzaniga et al., 1998; Miller et al., 2001), and this is likely implicated in self-regulatory capacity (Barkley, 1997; Fuster, 1989). McClure, Liabson, Loewenstein, and Cohen (2004) have demonstrated that the frontal areas are associated with a tendency to select larger later rewards over smaller earlier rewards in decision-making tasks; this, of course, is the instantly recognizable conundrum encountered by those trying to resist health damaging behaviors with appetitive qualities (e.g., tasty *vs.* unhealthy food; pleasant stimulation *vs.* risk of disease/illness).

The anterior cingulate. Recent interest in the ACC for its putative role in behavioral self-regulation has been driven by both anatomic and functional findings. Regarding the former, Paus (2001) reviews evidence highlighting three characteristics that implicate the ACC in behavioral self-regulation: (1) the fact that the ACC is imbued with reciprocal projections with prefrontal areas, thus implicating the ACC in execution of higher cognitive processes like goal setting and attention; (2) the presence of projections from the ACC to the motor cortex and the spinal cord, thus supporting the contention that the ACC has a direct role in the control of behavior; and (3) the existence of afferents from the midline thalamic and brainstem monoamine nuclei, suggesting that the activation of the ACC may be dependent on the presence of drive states. The convergence of these three anatomic characteristics, according to Paus (2001), uniquely "provides the ACC with the potential to translate intentions into actions" (p. 417).

Functional neuroimaging studies have also provided support for the role of the ACC in the willful execution of behavior. Paus and colleagues observed consistent and response-specific activation of the ACC under conditions of response conflict using positron emission tomography (PET; Paus, Petrides, Evans, & Meyer,

1993). In the paradigm used, participants were impelled to execute a response that was in conflict with an overlearned stimulus-response association, with conditions of varied response modality (manual, verbal, or oculomotor); execution of each response resulted in activation of the ACC under conditions of conflict, and the particular area of the ACC activated appears to be specific to modality of response. This finding—particularly with respect to motor responses—was found to be quite robust in a meta-analytic review of 107 PET activation studies (Paus, Koski, Caramanos, & Westbury, 1998). Significant evidence also exists in favor of the assertion that ACC activation is accompanied by co-activation of the PFC (Koski & Paus, 2000), and findings that transcranial magnetic stimulation of the mid-dorsolateral PFC results in quantifiable blood flow response in the ACC (Paus, Castro-Alamancos, & Petrides, 2000).

In summary, although the precise nature of the role of the ACC remains somewhat open to debate (e.g., Carter, Braver, Barch, Botvinick, Noll, et al., 1998; Gehring, Goss, Coles, Meyer, & Donchin, 1993), there is strong consensus that it is centrally involved—along with the prefrontal areas of the human cortex—in the task of behavioral self-regulation.

Application of self-regulatory abilities to health behavior

As described earlier, TST makes the specific prediction that subtle, naturally occurring differences in brain function between and within individuals should be associated with health behavior patterns, given the necessity of continual suspension of prepotent responses (or maintenance of non-response) for healthy behavior performance. In an initial study, we demonstrated that, as would be predicted from TST, individual differences in brain function were positively associated with health risk behaviors, and these effects seemed to be specific to frontal function and not general cognitive ability (Hall, Elias, & Crossley, 2006). Moreover, in subsequent studies, we have found that individual differences in frontal function strongly moderate the strength of association between intention and action for a variety of health behaviors. For example, among those with weak executive function, intention was only minimally predictive of exercise and dietary behavior over a 1-week interval; among those with strong executive function, intention was much more strongly predictive of these two behaviors over the same time interval (Hall, Fong, Epp, & Elias, 2007). This moderational effect seemed to generalize to the behavior of alcohol consumption as well (Hall & McEown, 2005). Not only does this call into question the notion that health behaviors are regulated exclusively by intention, it also supports the central postulate of TST that self-regulatory capacity constitutes a dispositional variable of interest in predicting behavior patterns in environments where such behaviors are associated with dramatically different valences of immediate and delayed contingencies.

As described earlier, Paus (2001) has proposed the existence of a self-regulatory circuit in the brain consisting of the prefrontal cortex and the anterior cingulate. The former is implicated in the forming of intention and attentional

resources required to carry out associated actions, whereas the latter is implicated in effortful self-regulation in the presence of conflicting demands. Conflict is the very state of affairs that we have argued is characteristic of many health behaviors vis-à-vis the temporal disjunction of costs and benefits, and the requirements to withhold response to immediate cues for the sake of non-immediate considerations. Strong connections between the anterior cingulate and the dopamine-modulated control of behavior reinforce the grouping of these two areas in the regulation of health behaviors.

In a recent functional imaging study, we have found confirmation of the role of the ACC in self-regulation of health protective behavior (Hall, Elias, Fong, Borowsky, Harrison, et al., 2006). This study consisted of two phases. In the prospective behavioral phase, we asked participants to articulate intentions for physical activity for the upcoming 7 days, and then furnished them with a tri-axial accelerometer to measure physical activity continuously during waking hours over the course of the subsequent week. We then calculated intention-behavior discrepancies for those with initially high intentions, and created two groups: (1) those who were characterized by high intention-behavior continuity (“successful self-regulators”); and (2) those who were characterized by low intention-behavior continuity (“unsuccessful self-regulators”). Members of both groups-matched on age, gender, and ethnicity – were invited to participate in a functional imaging phase wherein they completed a number of computer tasks during imaging including a non-challenging version of the Stroop task, a task known to be associated with ACC function (Pardo, Pardo, Janer, & Raichle, 1990). All participants were also given a standardized test of general cognitive function. Unsuccessful self-regulators were differentiated from successful self-regulators in terms of general cognitive function and in magnitude of activation in the ACC region of the frontal lobes during the Stroop task. Specifically, the unsuccessful self-regulators demonstrated stronger activation in the ACC while performing the Stroop than successful self-regulators, suggesting heavier recruitment of resources from this area during performance of the task. In addition, neuropsychological testing revealed that unsuccessful self-regulators were strictly average in terms of IQ, whereas successful self-regulators were in the “superior” IQ range, demonstrating a full standard deviation advantage over unsuccessful self-regulators and 22.5 points higher the expected general population mean. These findings further reinforce the notion the self-regulatory capacity is an important but under-explored facet of individual health behavior, and that self-regulatory resources may be at least partially biologically-imbued.

Interestingly, several well-designed large scale studies have demonstrated that individual differences in performance on tests of general cognitive function (*g*) in childhood and adolescence are associated with morbidity and mortality in later life (Deary, Whiteman, Starr, Whalley, & Fox, 2004; Gottfredson, 2004; Gottfredson & Deary, 2004; Hart et al., 2003). With respect to morbidity, the predictive power of *g* is especially strong for the development of illnesses that are heavily dependent on behavioral self-regulation to prevent (e.g., diabetes; Gottfredson, 2004). Although these findings do not specifically implicate the

frontal lobes, performance on most tests of g is highly dependent on frontal lobe function. In fact, some have argued that some aspects of prefrontal function (i.e., working memory) and g are one in the same (Engle, 2002). As such, at least some of the association between performance on IQ tests and morbidity/mortality may be attributable to individual differences in self-regulatory capacity, and this opens up the intriguing possibility that health behavior is a mediator of these well documented effects. This represents an area of inquiry deserving of further investigation.

Other facets of self-regulatory capacity

The prefrontal cortex has undergone exponential growth in our species over recent evolutionary history. It is more developed in humans than in most primates (but see Semendeferi, Lu, Schenker, & Damasio, 2002), and is generally more developed in primates than in animals lower on the phylogenetic scale (Gazzaniga et al., 1998). This growth has potentiated a variety of cognitive self-regulatory operations that can enhance the capacity for purely cognitive self-control (Mischel et al., 1989; Moore, Mischel, & Zeiss, 1976). Although the ability to inhibit prepotent responses in the interests of long-term contingencies is not a uniquely human capacity (Grosch & Neuringer, 1981; Rachlin & Green, 1972, 1986), it could be argued that the existence of well developed frontal lobes potentiates the use of cognitive strategies that profoundly augment an organism's capacity for behavioral self-regulation in all domains, including health behavior. Indeed, there has been longstanding interest in the cognitive activities (e.g., goal-setting, self-monitoring) that give rise to improved enactment of health protective behaviors (Bandura, 1997; Carver & Scheier, 1998; Locke & Latham, 2002), and increasing focus on self-regulatory processes in more recent models of health behavior (e.g., Schwarzer, 2001).

Mischel et al. (1989), for example, have demonstrated that children who are taught to attend to the non-appetitive qualities of treats put before them are more able to delay gratification to attain a larger, later reward than children who are taught to attend to the more salient appetitive qualities of the treats. Mischel et al. observed that the beneficial effects of these cognitive strategies are apparent for children who normally have difficulty delaying gratification, and are used spontaneously (i.e., without prior instruction) more often among those children who perform well on the delay of gratification task than those who perform poorly on it. These effects are quite robust, and attest to the power of volitional cognitive strategies to facilitate behavioral self-control.

Volitional self-control of this variety may come with a price, however. Contemporary work by Baumeister and colleagues have demonstrated that conscious efforts to inhibit prepotent responses (both reflexive emotional responses and natural cognitive tendencies) can lead to compromised self-control capacity on tasks immediately following initial self-control efforts. In a series of studies, Muraven, Tice, and Baumeister (1998) asked participants to engage in a task that required suspension of a prepotent response (e.g., not laughing while

watching a funny movie), and observed that performance of these participants was reduced on subsequent, unrelated self-control tasks relative to controls who were not required to self-regulate initially. Findings from this line of research suggest that self-control—conceptualized here as the ability to override a prepotent response—is a limited resource that is subject to energy depletion (Muraven & Baumeister, 2000) and perhaps even conservation (Muraven, Shumeli, & Burkley, 2007).

Studies of self-regulation, then, suggest that continual suspension of prepotent responses (as required for maintenance of healthy behaviors in unhealthy environments) may exact an energy cost. If so, energy may put a limit on self-regulatory capacity for each individual from moment to moment in the same way that self-regulatory capacity is potentially limited by individual differences in brain function. Momentary depletion of energy may cause lapses in ability to suspend prepotent responses, as would dispositional (between-individual) differences in mean energy level put limits on the capacity to suspend prepotent responses over time.

Some indirect support for the position that future-oriented behavior requires energy comes from several studies (Goldberg & Maslach, 1996; Zimbardo & Boyd, 1999) showing that individual differences in the future subscale of the Zimbardo Time Perspective Inventory (ZTPI) correlate strongly and positively with self-reported energy (Zimbardo & Boyd, 1999). In addition, a recent study by Rhodes, Courneya, and Jones (2004a) demonstrated that the “activity” facet of the extraversion personality trait predicts exercise behavior over and above that accounted for by intention, and associated social-cognitive constructs. A second study by the same authors suggests, consistent with the postulates of TST, that trait energy moderates the association between intention and behavior for exercise: higher levels of dispositional energy strengthen the connection between intention and behavior (Rhodes, Courneya, & Jones, 2004b). Although the authors did not control for the potentially confounding effects of past behavior in their analyses, this does provide some support for the notion that *dispositional* energy is a facet of self-regulatory capacity that may be important for engaging in healthy behavior over time, a notion that is not accounted for well by any existing theories of health behavior.

A *state* energy depletion explanation also reveals why many lapses in self-regulatory behaviors in health are associated with taxing experiences or low activation mood states, such as sadness. Support for this notion comes from correlational and experimental work demonstrating that negative moods precipitate breakdowns in self-control in a variety of domains of health behavior, including smoking cessation (Brownell, Marlatt, Lichtenstein, & Wilson, 1986; Shiffman, 1982) and dieting (Heatherton, Herman, & Polivy, 1991; Heatherton, Striepe, & Wittenberg, 1998).

To what extent do energy explanations for self-regulatory lapses represent something independent from frontal lobe function? In fact, self-regulatory fatigue effects operate in ways that are clearly predictable with reference to the underlying physiology and function of the human cerebral vasculature/metabolic system, and

the operation of the frontal lobe specifically. Self-regulatory fatigue effects appear to be reliant on glucose (Gailliot et al., 2007) which has long been known to effect cognitive function (Korol & Gold, 1998; Korol, 2002). In short, the rather mysterious resource underlying self-regulatory fatigue effects may be not so mysterious after all,² but may nonetheless affect behavior in a manner analogous to other facets of self-regulatory capacity outlined in the TST model.

Motivational prerequisites for future-oriented behavior

According to the expectancy-value approach espoused by Rotter (1954), Bandura (1977, 1986), and Fishbein and Ajzen (1975), motivation to reach any desired long-term outcome should be a function of: (1) how much one values the outcome; and (2) the strength of one's belief that the occurrence of this outcome is contingent on one's current behavior. These values and beliefs arise from a variety of social influences including family, peer groups, and culture of origin, as well as personal experience. As such, they may vary from individual to individual within populations, in much the same way as biological and cognitive elements. However, values and beliefs may also vary from one population to the next, and among cultural groups within a given population. For example, it might be expected that individuals living under circumstances where the average life expectancy is significantly reduced (e.g., war-torn regions of the world, or disease-stricken populations) would have attenuated strength of belief in the connectedness of present actions with later outcomes. This could occur via the operation of social sanctions against holding unrealistic long-term goals, and/or the existence of objectively tenuous connections between immediate behavior and the realization of long-term outcomes. Indeed, it has been demonstrated previously that low socioeconomic status is associated with a truncated horizon of personally relevant future, and with a general orientation to the present (e.g., Lamm, Schmidt, & Trommsdorff, 1976; Lessing, 1968; Nurmi, 1987).

As depicted in Figure 5, both motivational (i.e., *motivational sphere*) and environmental variables (i.e., *ambient temporal contingencies*) are represented in the TST framework. Within the motivational sphere, and in agreement with social-cognitive models, TST posits that intention is formed based on expectancy-value components, which vary along a temporal dimension. Contrary to existing social-cognitive models, however, intention is only one of the proximal determinants of behavior, along with behavioral prepotency and self-regulatory capacity. Moreover, both behavioral prepotency and self-regulatory capacity have the ability to moderate the strength of association between intention and observed behavior.

Temporal factors influence behavior at several levels, including the expectancy-value component of the model (as indicated above), as well as the ambient environmental contingencies for behavior that vary between immediate and non-immediate. For example, motivation (i.e., behavioral intention) to attend a fitness class might be determined by expectancy that exercising will eventually result in improved physical appearance, and the value attached to looking "fit". This motivation would have a strong association with the likelihood of actually

attending the class, however actual attendance (i.e., *observed behavior*) would also be dependent on frequency of past attendance and state or trait variability in capacity to self-regulate (i.e., overcome inconvenience, time cost) to actually make it to the class on the occasion in question. Moreover, the ability of the individual to translate their intention into behavior would be strengthened or weakened—that is, moderated—by either of these factors, and the ambient environmental contingencies (i.e., proximity of the fitness facility, availability of transportation) simultaneously influence the magnitude of prepotency, the amount of effortful self-regulation required, and the actual outcomes of the decision to attend. Thus, final performance of any health behavior is determined by intention, self-regulatory capacity, behavioral prepotency, and the ambient environmental contingencies associated with behavioral performance. With this analysis, we begin to see why adherence to programs of physical activity is significantly lower than what would be warranted by an entirely rational analysis (Dishman, 1991).

Feedback loops in the self-regulatory system

Feedback loops are a common component of self-regulatory models of human behavior (Carver & Scheier, 1998; Schwarzer, 2001). Following early mechanistic models of self-regulation (Miller, Galanter, & Pribram, 1960), recent theorizing has emphasized the importance of acknowledging different phases of the behavioral change process (Rothman, 2000; Rothman, Baldwin, & Hertel, 2004). There appears to be good empirical justification for this assertion. For example, Baldwin et al. (2006) found that among a sample of smokers enrolled in a structured smoking cessation program, self-efficacy for quitting predicted future quit status for those who recently initiated their quit attempt, while satisfaction regarding the outcomes of their quit efforts predicted quit status for those quitters who were struggling to maintain abstinence. Likewise, in the weight loss domain, Linde, Rothman, Baldwin, and Jeffery (2006) found that self-efficacy's ability to predict successful weight loss was stronger for new initiators than for maintainers. In short, behavioral change may not take place in a linear fashion, and feedback based on experience may be especially important to consider as the behavior is performed (or refrained from) over extended periods of time.

Such temporal unfolding of change can be explained by reference to feedback loops in Figure 5. According to TST, the relative importance of satisfaction, for example, may arise from cumulative feedback from behavior to the expectancy-value component of the motivational sphere. Those who experience positive outcomes may come to believe that the balance of future costs and benefits of continuation of the behavioral change (i.e., maintenance) will be worth it; that is, the likelihood of positive outcomes given the next performance of the behavior is strengthened, or value of the future experience of the outcome is enhanced by prior experience. As such, TST captures the influence of experiential aspects of the behavior change process on future behavior change efforts, a dynamic that has been

receiving increasing attention in the empirical literature on health behavior change (Baldwin et al., 2006; Jeffery, Kelly, Rothman, Sherwood, & Boutelle, 2004).

In addition to the effects of behavior on connectedness beliefs and temporal valuations, it may also influence constructs outside the motivational sphere. For example, performance of a behavior over time—by definition—affects behavioral prepotency. One of the central tenets of TST is that behavior takes on a kind of psychological inertia as performance is repeated over time. The exact mechanism by which this takes place is beyond the scope of this model however, as described, some have suggested that habit strength is generated when behaviors are performed with high frequency in stable situational contexts (Ouellette & Wood, 1998; Wood, Tam, & Witt, 2005).

Finally, it is expected the performance of behaviors may form a feedback loop with self-regulatory capacity. Indeed, there is accumulating evidence to suggest that some health behaviors can influence brain function when repeated with consistency over time. For example, it is now well-established that the relation between brain function and aerobic exercise is bidirectional. In addition to our own prospective studies showing an augmenting influence of executive function on intention-behavior continuity for exercise behavior, several studies have documented the augmenting influence of aerobic training (specifically) on brain function (Colcombe et al., 2004; Hillman et al., 2006).

In summary, behavioral experience may affect beliefs and valuations of the behavior in a manner consistent with the conceptualization of Rothman (2000) of the change process. Likewise, behavioral performance, by definition, influences prepotency and—depending on the behavior—could influence subsequent self-regulatory capacity. Importantly, all of these relationships are conceptualized within TST to represent cumulative feedback loops that do not have a strong and deterministic effect back on their predecessors. As such, they are indicated with broken rather than solid lines in Figure 5, denoting the secondary but cumulative influence of behaviors on the aforementioned constructs.

TST and other models of health behavior

Most social cognitive models of health behavior share the conviction that behavioral contingencies are important determinants of health behavior, although most add the proposition that perceptions of contingencies are more important determinants of behavior than actual contingencies. The Theory of Reasoned Action (TRA; Fishbein, 1967) and Theory of Planned Behavior (TPB; Ajzen & Madden, 1986), Social Cognitive Theory (Bandura, 1977), and the Health Belief Model (HBM; Becker, 1974; Rosenstock, 1966) all incorporate constructs that pertain directly to perceived behavioral contingencies (see Table II). However, in some of these models, contingencies are represented in ways that may gloss over important nuances regarding the timeframe over which the behavior occurs, and the characteristics of the behavior itself.

For example, the TRA and TPB both hold that beliefs about the probable outcomes of one's behavior (i.e., behavioral beliefs) are important determinants

Table II. Behavioral contingencies as operationalized by existing social-cognitive theories.

Theory	Construct	Definition
Theory of Reasoned Action; Theory of Planned Behavior (Ajzen & Madden, 1986; Fishbein, 1967)	Behavioral beliefs/values	Outcomes or consequences of a particular behavior/values attached to these consequences or outcomes.
Social Cognitive Theory (Bandura, 1977)	Expectancies/expectations	Anticipated outcomes of a behavior/values attached to these outcomes.
Health Belief Model (Becker, 1974; Rosenstock, 1966)	Perceived benefits/perceived barriers	Perceptions of benefits/costs associated with a health action.
Temporal Self-Regulation Theory	Connectedness beliefs/temporal valuations	Strength of connectedness between present actions and anticipated outcomes/values attached to anticipated outcomes.

of actual behavior through their influence on more proximal social-cognitive variables. Although the operationalization of behavioral beliefs is straightforward when explaining discrete behavioral choices (i.e., choosing to vote for political candidate “A” *vs.* candidate “B”), it becomes less clear when applied to health behaviors which, by their nature, are action sequences performed over long periods of time (Sheeran, Conner, & Norman, 2001). Perhaps more problematic is that fact that the original articulations of TRA and TPB do not include temporal weighting of anticipated contingencies. That is, a benefit that is perceived to occur immediately upon initiation of the behavior (e.g., the euphoric rush from nicotine ingestion) is weighted equivalently with one that is to be realized only after several weeks of repeated behavior (e.g., weight maintenance). The psychological equivalence of proximal *vs.* distal rewards—or costs, for that matter—is questionable given that temporally proximal contingencies tend to be disproportionately more valued than temporally distal contingencies (Lowenstein & Thaler, 1989). The temporal valuation issue is not adequately addressed in current articulations of the TRA/TPB, although it could be addressed with more complex weighting schemes that include a temporal component.

Some links also exist between TST and Social-Cognitive Theory (SCT), as proposed by Bandura (1986; 1997). The concept of outcome expectancies—referred to as “connectedness beliefs” in TST—is represented as a unique determinant of behavioral intention. According to both SCT and TST, those who estimate a high probability of a positive outcome given performance of a behavior would be more highly motivated to engage in that behavior. Past experimental studies have demonstrated that outcome expectancies are indeed causally associated with intention formation for health behaviors (e.g., Maddux, Sherer, & Rogers, 1982). The construct of self-efficacy is also folded into the TST model. To the extent that self-efficacy represents, in part, a reading of one’s own likelihood of future self-regulatory success based on one’s past experiences with

the behavior in question, it could be argued that self-efficacy is represented by the feed-forward and feedback loops between self-regulatory capacity and behavior (either through intention or directly without intentional mediation). For example, someone who formed an intention to exercise last week but did not attend their most recent fitness class, might experience lowered strength of belief regarding their ability to enact future intentions to exercise. This might lower the likelihood of future exercise class attendance. This portion of the TST model, then, would represent a special instance of reciprocal determinism with respect to self-efficacy, past behavior, and future behavior.

Finally, there is some overlap between the Transtheoretical Model (TTM; Prochaska et al., 1992) of health behavior and TST vis-à-vis the notion of *decisional balance*, a concept originally developed by Janis and Mann (1977) in their model of human decision-making. Briefly, the TTM suggests that individuals' progression to the "action" (i.e., active) stage of behavior change is dependent on the pros of a behavior outweighing the cons, thus inducing motivation for change (Prochaska et al., 1994). As such, TST is allied with TTM in its conviction that anticipated outcomes are important determinants of behavior. However, as originally articulated by Prochaska et al. (1994), decisional balance does not include an explicit provision for temporal dimensions of pros and cons. As such, TST adds some precision to the original conceptualization of the relationship between decisional balance and motivation for behavior change.

In summary, while we accept the importance of the expectancy-value approach for understanding deliberative influences on behavior, we propose that inclusion of a temporal component in the model represents an important re-thinking of the TRA/TPB. It is reasonable to ask: "to what extent does the current model represent a re-arrangement of the TPB *vs.* a truly novel framework?" To some extent, TST could be viewed as a re-conceptualization of TPB through the lens of contemporary perspectives from behavioral economics and cognitive neuroscience. However, it is clear that TST includes new constructs—e.g., behavioral prepotency, and biological facets of self-regulatory capacity—that are not contained in the TRA/TPB, and other constructs are substantially re-ordered. In addition, although necessarily tentative at this early stage of theoretical development, there is an explicit incorporation of environmental context dynamics (i.e., ambient temporal contingencies), providing a potential point of interface between this individual model of health behavior and more macro-level ecological models of health behavior that may emerge in the future. Michie, Rothman, and Sheeran (2007) have emphasized the importance of tentativeness and willingness to adapt theoretical concepts after introduction of the original articulation of the theory. We present the ecological interface of the model as an "open-source" platform for further exploration and refinement as our understanding of the interaction between individual and ecological factors increases.

One concept that seems superficially common to both TPB and TST is the control dimension (perceived control in TPB; self-regulatory capacity in TST).

According to TPB, intentions should be strengthened to the extent to which the behavior is perceived to be more controllable, and perceived controllability should also affect behavior directly. In TPB, controllability is described as a fully cognitive variable independent from actual control. TST, on the other hand, suggests that actual control (in the form of self-regulatory abilities) is influential on behavior independent of perception. In their review of the extant experimental literature on the issue, Webb and Sheeran found both perceived and actual controllability have a moderating influence on the intention-behavior relationship, but induced increases in perceived control do not work additively with induced increases in intention. In fact, if anything, perceived control induction weakens the effects of intention induction on behavior. In short, control is an important variable, but the causal significance of perceived control (as opposed to actual control) is unclear based on the existing experimental evidence. It is also important to note that the structural relationships among intention, control, and behavior are different in TST and TPB. While TPB posits that perceived control is independently associated with intention and independently associated with behavior, TST posits that actual control (self-regulatory capacity) moderates the intention-behavior link, in addition to its direct effects on behavior. As described earlier, there exists both theoretical justification and empirical evidence to support the moderational assertion inherent in the TST arrangement of structural relationships (Hall et al., 2007; Webb & Sheeran, 2006). Finally, and perhaps most importantly, TST depicts neuro-cognitive and social-cognitive factors as representing interacting, rather than separate, levels of analysis. Rather than making reference to only perceived abilities to control behavior, TST makes reference to actual controllability vis-à-vis internal self-regulatory abilities of the actor, thus making the strong prediction that brain function will interact with intention formation processes to influence likelihood of actual behavioral performance. This represents a significant point of departure from previous social-cognitive models, and from TPB in particular.

Other models of intertemporal choice

The phenomenon of inter-temporal choice is potentially quite relevant to health behaviors that inherently involve short- and long-term tradeoffs. Several models of inter-temporal choice have come from behavioral economics, and perhaps the most prominent is that articulated by Ainslie (1975; 2001). Ainslie's model suggests that self-defeating behavior stems from the interaction of two phenomena: hyperbolic discounting of outcomes, and intertemporal bargaining between selves with differing vested interests. Briefly, hyperbolic discounting refers to the phenomenon of differential valuation of rewards as a function of proximity in time: the value of rewards increases dramatically as they become more proximal. This increase is not simply linear (or even exponential) but hyperbolic, thereby explaining seemingly irrational reversal of preferences from larger later rewards towards immediate smaller rewards at the time of choice. These reversals are not explainable from a linear or exponential increase in valuation as proximity increases. Intertemporal

bargaining is a descriptive label attached to the process of negotiation between temporally dispersed selves (i.e., the “short-term-self” *vs.* the “long-term-self”) that can result, under some circumstances, in behavior that seems to ultimately be against the interest of the unitary self.

While this is a well-articulated model that is clearly superior to older economic choice models of behavior, several differences exist between TST and Ainslie’s model as applied to the special case of health behavior. The first is that Ainslie’s model is a purely cognitive one. No reference is made to biological processes or structures that aid in the behavioral implementation of choice; although they are assumed to underlie the evaluation of factors in the choice itself. A second major point of divergence is the definition of the construct of interest. Like many choice models of self-defeating behavior, there is little to suggest that there is any difference between making a discrete choice to behave in a certain way, and an actual longstanding behavior pattern. In a way, this makes good sense: as long as the intention-behavior link is hidden, there is no role for self-regulatory capacity. However, one of our major contentions is that intention-behavior discrepancy is the norm rather than the exception, particularly where health behaviors are concerned. Although Ainslie’s model does include reference to the same temporal issues as explained by TST in terms of valuations of non-immediate outcomes, and cognitive conflict generated by same (in fact, with reference to much of the same research literature on intertemporal choice), it stops short of acknowledging the importance of biological structures in explaining individual differences in tendencies toward self-defeating behavior. This, in our view, is a critical omission.

Construal Level Theory (CLT; Trope & Liberman, 2003) represents another temporal lens for understanding human behavior. Briefly, CLT holds that any given object or event can be construed at multiple levels of specificity, each of which have differential implications for judgment, decision-making, and behavior (Fujita, Trope, Liberman, & Levin-Sagi, 2006). High-level construals of objects and events are predominantly abstract conceptualizations of object-relevant information; they tend to include essential features that are global and general in quality. Low-level construals are detailed and highly specific to the instance of the object or event encountered; they are subordinate and incidental in quality. Compared to individuals induced into low-level construals, individuals induced into high-level construals articulate stronger intentions to endure low-level costs in the interests of attaining valued high-level benefits (Fujita et al., 2006). As such, CLT provides a framework to understand short- *vs.* long-term tradeoffs, and would potentially provide an alternative conceptualization to the expectancy-value portion of the TST framework when explaining intention formation.

Despite its theoretical elegance and its utility as an explanatory framework for discrete lab-based behaviors, there are several limitations of the CLT framework when applied to the task of explaining repetitive health behavior tendencies in the real world. Perhaps the most important limitation of CLT is that it is an entirely cognitive explanation for what we believe is fundamentally a biopsychosocial phenomenon, influenced not only by cognitive processes such as those suggested

by CLT, but also the ecological context in which the behavior occurs, the past behavioral tendencies of the individual, and biologically-imbued self-regulatory abilities. Moreover, the existing empirical research on construal level utilizes dependent measures that are normally considered to be social-cognitive predecessors to action (i.e., intentions, values, judgments) rather than action itself. Even for the most proximal of social-cognitive variables, the association with behavior is notably complex and frequently over-stated (Webb & Sheeran, 2006). Nonetheless, the concept of psychological distance is potentially related to the motivational sphere of TST; exactly *how* it is related remains an open question.

At present, our preference is to define the motivational sphere with reference to a temporally sensitive variant of the expectancy-value approach – this is the most conservative approach given this early stage of theory development. Future research on temporal construal may very well suggest a more nuanced incorporation of construal into the TST framework. This will be dependent on demonstration that construal level is influential for repetitive health behaviors, and those that occur outside of the laboratory context.

TST and temporal orientation

Empirical research regarding individual differences in time perspective—that is, dispositional tendencies to behave in accordance with short- *vs.* long-term contingencies (Hall & Fong, 2003; Strathman et al., 1994; Zimbardo & Boyd, 1999)—and health behavior has been renewed over the past decade, after seminal research in the field of education in the middle part of the last century (e.g., Teahan, 1958). Contemporary studies have demonstrated that individual differences in time perspective are associated with health relevant decision-making processes (Orbell & Hagger, 2007; Orbell, Perugini, & Rakow, 2004), risky driving behavior (Zimbardo, Keough, & Boyd, 1997), and smoking behavior (Fong & Hall, 2003). Though the effect sizes tend to be small in magnitude, stronger long-term orientation (or weaker short-term orientation) appears to be negatively associated with risky behaviors, and positively associated with health protective behaviors.

What causes individual differences in the tendency to behave consistently in accordance with long-range contingencies? TST poses a partial answer to this question, making reference to interactions among social-cognitive, neuro-cognitive, and ecological forces. Although direct concordance between TST and the personality disposition of “time perspective” is unlikely, the temporally stable facets of TST constructs (e.g., stable manifestations of self-regulatory abilities, stable cross-domain goal orientations) would roughly correspond to personality types suggested by measures of time perspective. For example, a “long-term oriented” individual might have strong biologically-imbued self-regulatory abilities and a tendency to place high value on non-immediate contingencies across multiple domains, and therefore display a tendency to behave consistently in accordance with long-range behavioral contingencies.

To the extent that constructs, like time perspective, reflect accurate self-readings of one's own dispositional cognitive and behavioral tendencies over the course of one's lifetime (i.e., "I tend to do things that are in my long-range interests") in a manner roughly analogous to the process suggested by Self-Perception Theory (Bem, 1967), there may be some statistical concordance between TST constructs and self-report measures of time perspective. That is, some individuals may be able to accurately read their proclivities toward self-regulatory success or failure (and associated motivations) over their lives, and infer stable dispositions from these; these inferences may, in turn, manifest in response patterns to self-report personality questionnaires, like the *Zimbardo Time Perspective Inventory* (Zimbardo & Boyd, 1999), *Consideration of Future Consequences* scale (Strathman et al., 1994), and the *Time Perspective Questionnaire* (Fong & Hall, 2003). Ultimately, this is an empirical question that has yet to be explored thoroughly; our suspicion is that such associations would be more likely to hold with reference to dispositional facets of TST constructs and when multiple behavioral domains are aggregated.

In summary, TST provides a potential explanation of how stable individual differences in behavioral tendencies arise, in that dispositional facets of motivation and self-regulatory abilities may enable (or hinder) health promoting behavior over time. To the extent that individuals are aware of and self-reflective on these tendencies, they may manifest in responses to contemporary self-report measures of dispositional time perspective. To date, associations between dispositional time perspective and health behavior—while present—have been relatively small in magnitude and inconsistent across behaviors (Chapman, 2005; Fong & Hall, 2003; Zimbardo & Boyd, 1999). As an applied theoretical framework, TST should explain behavioral tendencies with higher precision than time perspective alone, given its reference to both stable and changeable facts of motivation- and ability-related variables, and its predominant domain-specificity.

Some caveats: impurity, emotionality, and uncertainty

Although we have described TST's primary components and discussed ways in which it relates to other models and lines of research, some caveats are in order at this point.

First, one central assumption of TST is that proximity and valence are substantially confounded for health behaviors, such that health risk behaviors are characterized by immediate benefits and non-immediate costs; health protective behaviors, on the other hand, are characterized as having largely non-immediate benefits, but immediate costs. For the most part, this pattern has held up to empirical scrutiny in our studies. However, on both a subjective and empirical level, health protective behaviors are not without their hedonic virtues. Physical activity, for example, can be associated with subjective feelings of enjoyment, depending on the person and the nature of the activity. Indeed, personal enjoyment is a strong predictor of physical activity adherence and participation

in sports (e.g., Gould, Feltz, & Weiss, 1985; Hardy & Rejeski, 1989). This is entirely consistent with the notion that immediate contingencies—which include hedonic aspects of engaging in the behavior itself—are disproportionately influential on human behavior. Unfortunately, few health protective behaviors are imbued with such positive hedonic qualities. Flossing one's teeth is rarely a pleasurable experience; wearing a condom is less pleasurable than going without; low-fat food is generally less tasty than high-fat food for both humans and animals. The lack of positive hedonic value goes a long way, of course, in explaining why humans so inconsistently perform these behaviors with the regularity that health promotion researchers and clinicians would prefer. When moving from health protective behaviors to health risk behaviors, however, hedonic virtues quickly turn to vice. Most of the hedonic qualities associated with health risk behaviors impel their performance regardless of the eventual outcomes. Use of recreational drugs results in pleasurable sensations (e.g., euphoria, relaxation, sociability, and/or sensory experiences) and provides an escape from unpleasant aspects of reality for the user; risky driving gives subjective feelings of “thrill” and power to the young male driver; unprotected sexual intercourse feels spontaneous, and pleasurable. In short, hedonic qualities of health risk behaviors are the very reason for their ubiquity despite the risks that they carry, and, in fact, may form the reason for their attraction (Goldberg, Halpern-Felsher, & Millstein, 2002).

In the end, hedonic qualities of health behaviors constitute a double edged sword that can occasionally facilitate health protective behavior, but more frequently impels risky health behaviors. Indeed, knowledge that a behavior is “risky” may even heighten its hedonic quality (e.g., “I know this is bad . . . but that's why it's so good!”). In short, although the confounding of temporal proximity (immediate *vs.* non-immediate) and contingency valence (cost *vs.* benefit) is not perfect in the real world—i.e., immediate or non-immediate contingencies are not always purely and uniformly opposite in valence—the general pattern seems to apply. Further, improving the hedonic qualities of health protective behaviors and dampening the hedonic quality of health risk behaviors may actually represent a potential avenue for creative intervention, and one that has been under-explored to date.

Second, some may suggest that TST does not sufficiently consider the importance of emotion in decision-making processes. Indeed contemporary approaches to decision-making increasingly incorporate affective processes, perhaps in reaction to earlier criticisms that such models were “too cognitive”. In fact, both experienced and anticipated emotionality have a clear place in TST as forms of immediate and non-immediate contingencies for behavior. That is, the experience of an aversive immediate emotional state should de-motivate a behavior in the same way as an immediate material contingency (e.g., time cost, inconvenience). For example, a novel exerciser may experience negative affectivity (e.g., embarrassment, self-consciousness) coincident with their experience of attending a fitness facility, and may, therefore, be inclined to eliminate this negative immediate influence by leaving quickly. This experience may also

color the exerciser's expectations about what would happen if they should attend the facility in the future, thereby adding an anticipation of aversive emotional state to their already growing list of costs associated with gym attendance (e.g., time cost, inconvenience). Ultimately, the experienced contingency is influential on an immediate basis (emotions typically are), but also plays a formative role for anticipated contingencies (i.e., connectedness beliefs). As such, within TST, emotions are both a potent form of subjectively experienced immediate contingency, and the subject matter of beliefs about anticipated future contingencies of behavioral performance.

Finally, it could be argued that one of the central features of non-immediate contingencies is their lower level of certainty of occurrence relative to immediate contingencies. This is particularly striking when risk reduction is considered as an outcome: how likely is it that smoking cessation will result in avoidance of lung cancer? Some individuals may contract cancer despite quitting. In TST, and many other models, decreased certainty of non-immediate outcomes can be accounted for by the connectedness beliefs construct. To the extent that an individual is properly calibrated to the actual probabilities, their assessment of their likelihood of realizing the outcome as a function of behavioral performance should influence intentions to perform the behavior (and perhaps valuation of the outcome itself). In reality, the mechanism by which immediate contingencies exert their potency is beyond the scope of TST; however, such discounting by certainty of occurrence does not change the well-established truism that immediate contingencies are disproportionately more influential on behavior than non-immediate contingencies, and this latter assumption is entirely consistent with TST. Interestingly, however, there is new evidence to suggest that the neural systems activated in decision-making under conditions of uncertainty are consistent with those suggested by TST as being essential for future-oriented behavior (Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005).

What is new about TST?

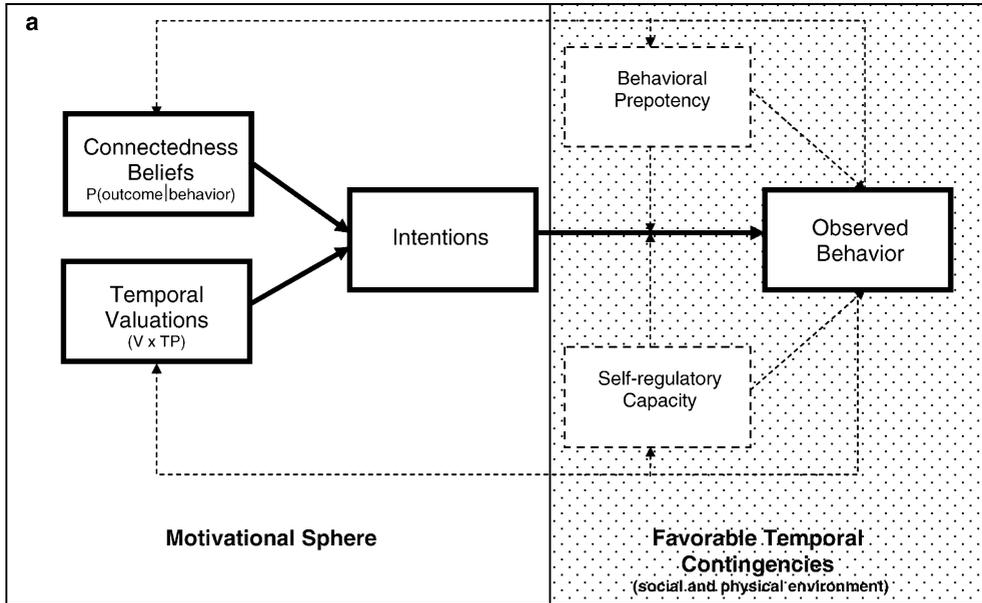
Several features of TST serve to distinguish it from its predecessors. First, TST is distinct in hypothesizing a biological basis for self-regulatory ability, a temporal basis for understanding behavioral contingencies, and an explicit focus on the interface between people and their social/physical environments. As such, TST provides a natural framework to consider individual- and ecological-level variables, while acknowledging the fundamental social and biological nature of human beings. Finally, understanding the *a priori* significance of past behavior is a novel contribution to the field of individual theories of health behavior.

Given the preliminary nature of research in support of TST, it is perhaps useful to articulate several *a priori* predictions that can be tested with future empirical work. Here are a few:

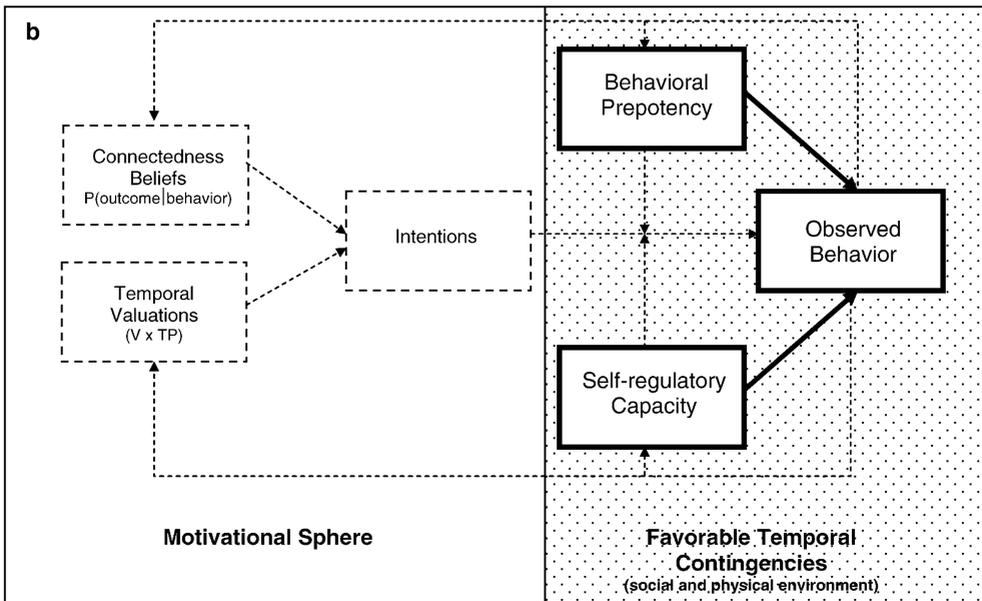
- The strength of association between intention and behavior will be moderated by state and trait variability in self-regulatory abilities (e.g., executive function) and by behavioral prepotency (e.g., past behavior).

- Strength of behavioral prepotency should be modifiable by ambient temporal contingencies in the social and physical environment, such that behaviors performed in non-supportive contexts will require more motivation and more self-regulatory resources; conversely, behaviors performed in relatively supportive environments should be primarily a function of behavioral intention and past behavior.
- Strength of intention to perform a behavior will be a joint function of probability of the aggregate outcomes given behavioral performance, and the value of these outcomes weighted by their perceived closeness in time; this can be represented with the following formula: $I = p(O|B) \times (V_0 \times TP_0)$, where I = behavioral intention, O = outcome, B = behavior, V = value of outcome, TP = temporal proximity of outcome.
- The relative predictability of behavior from intention, self-regulatory abilities and behavioral prepotency will depend on the ambient contingency structure of the social and physical environment in which the behavior occurs:
 - For discrete behaviors performed in relatively supportive ecological contexts (i.e., favorable ambient temporal contingencies), behavior will be primarily a function of intention, and secondarily a function of SRC and BPP (Figure 6a).
 - For repetitive behaviors performed in relatively supportive ecological contexts (i.e., favorable ambient temporal contingencies), behavior will be primarily a function of behavioral prepotency and self-regulatory capacity, and secondarily a function of intention (Figure 6b).
 - For discrete behaviors performed in relatively unsupportive ecological contexts (i.e., unfavorable ambient temporal contingencies), behavior will be primarily a joint function of intention and self-regulatory capacity, and secondarily a function of past behavior (Figure 6c).
 - For repetitive behaviors performed in relatively unsupportive ecological contexts (i.e., unfavorable ambient temporal contingencies), behavior will be a joint function of intention behavioral prepotency, and self-regulatory capacity (direct and moderational effects; Figure 6d).

There is already preliminary confirmation of some of these hypotheses, particularly the intention-moderation hypotheses (Hall et al., 2007). However, extensive empirical work will be required to fully test and evaluate the theory with reference to each of the stated hypotheses, and it is anticipated that incremental modifications or more significant revisions could (and should) be required as new insights emerge from social psychology, personality psychology, and the neurosciences.

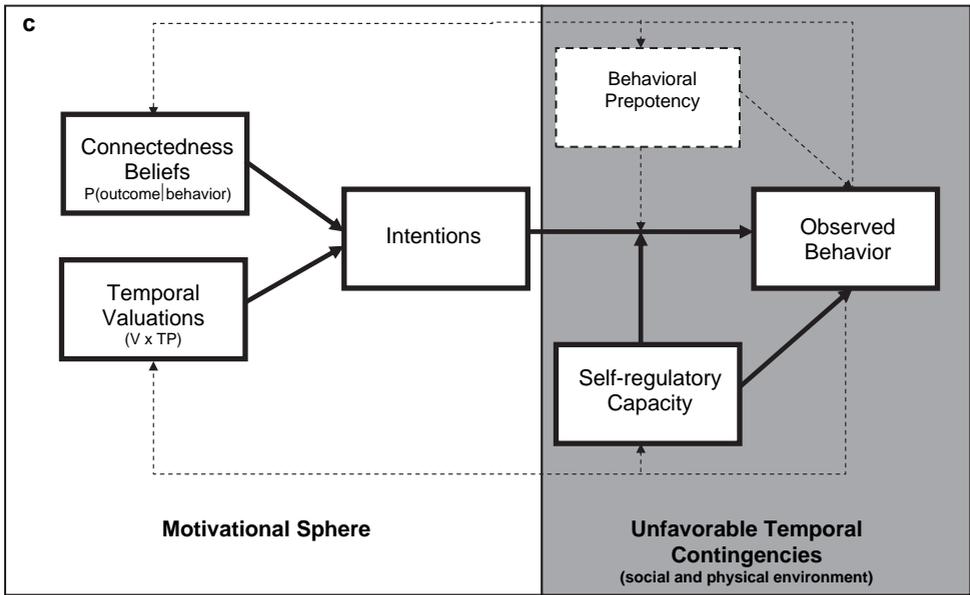


Note: Arrows between Behavioral Prepotency and Self-regulatory Capacity to the Intentions-Behavior arrow implies moderation. "Favorable temporal contingencies" are operationalized as predominantly positive, neutral, or minimally negative immediate contingencies for the behavior in question. Broken arrows denote weaker (i.e., secondary) hypothesized effects.

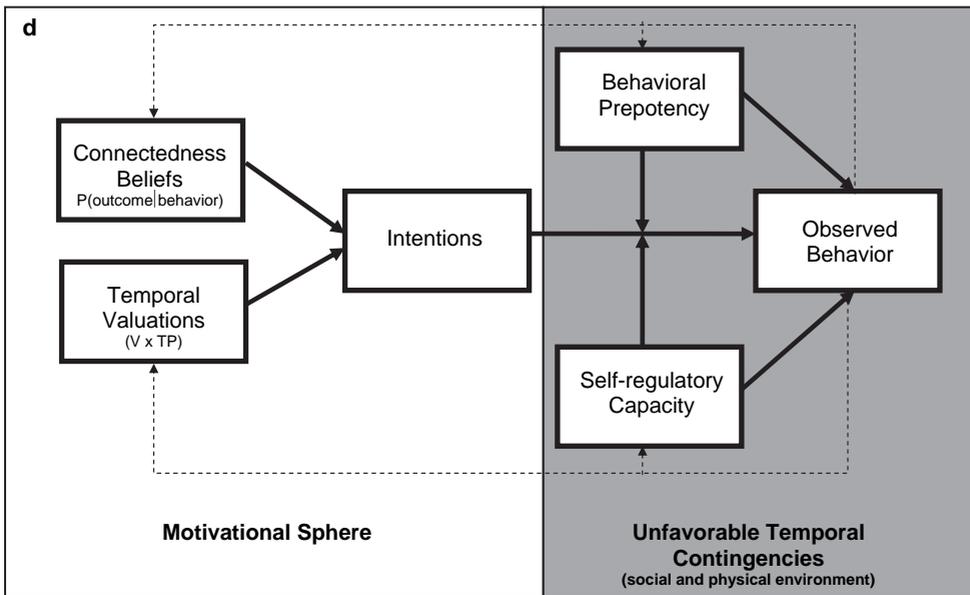


Note: Arrows between Behavioral Prepotency and Self-regulatory Capacity to the Intentions-Behavior arrow implies moderation. "Favorable temporal contingencies" are operationalized as predominantly positive, neutral, or minimally negative immediate contingencies for the behavior in question. Broken arrows denote weaker (i.e., secondary) hypothesized effects.

Figure 6. (a) TST v1.1; hypothetical model for low-demand, discrete performance behaviors, in supportive ecological context; (b) TST v1.2; hypothetical model for low-demand, repetitive behaviors, in supportive ecological context; (c) TST v1.3; hypothetical model for high-demand, discrete behaviors, in non-supportive ecological context; (d) TST v1.4; hypothetical model for high-demand, repetitive behaviors, in non-supportive ecological context.



Note: Arrows between Behavioral Prepotency and Self-regulatory Capacity to the Intentions-Behavior arrow implies moderation. "Unfavorable temporal contingencies" are operationalized as predominantly negative immediate contingencies for the behavior in question. Broken arrows denote weaker (i.e., secondary) hypothesized effects.



Note: Arrows between Behavioral Prepotency and Self-regulatory Capacity to the Intentions-Behavior arrow implies moderation. "Unfavorable temporal contingencies" are operationalized as predominantly negative immediate contingencies for the behavior in question. Broken arrows denote weaker (i.e., secondary) hypothesized effects.

Figure 6 (Continued)

Implications of TST for individual and population health

In the classic Skinnerian sense, behavioral contingencies are not static. They are determined by the environment, and will only remain stable as long as the environment remains stable (Skinner, 1953). Unfortunately, many industrialized environments have been engineered to pull for unhealthy behavioral practices in the name of economics. We are inundated with reminders about the easy availability of “fast” food. The fact that this food may also be unhealthy, for the most part, stems from the fact that corporations have to sell food in order to maximize profit. Human food choice appears to be primarily (although not exclusively) determined by taste (Drewnowski, 1997a), and clearly the fast food industry is aware of this preference. Therefore, the market dictates that a fast food corporation must appeal to these tastes if they want to sell food; indeed corporations are legally bound to maximize profit for shareholders, and this holds true even when doing so results in a net harm to the population at large (Bakan, 2004).

Humans unfortunately enjoy the taste of high sugar and high fat foods (Drewnowski, 1997b; Drewnowski & Greenwood, 1983), and this may reflect an evolved tendency that functioned to ensure survival of the species under conditions of food scarcity (Tiger, 2000). Regardless, existing evidence suggests that we find eating high fat foods very rewarding at the time we do it – the immediate contingencies are positive. As a result, we exist in a world where we are bombarded with brightly colored cues to consume convenient and tasty food. Part marketing strategy, part evolutionary hangover, we find ourselves consuming the very products that are implicated strongly in the development of chronic illnesses, such as heart disease and diabetes. If there is any kind of conspiracy by the fast food industry, it is not a conspiracy to make us die sooner; it is a conspiracy to make as much money as possible from a species that has demonstrated a strong taste (and buying) preference for high fat foods. Indeed, the strategy of adding fat to a food to enhance its flavor is well known amongst food preparers even outside of the fast food industry, and this is likely why restaurant meals on average have higher fat content than those prepared at home (Guthrie, Lin, & Frazao, 2002; Lin & Frazao, 1997).

Some may argue that we present a gloomy picture of human potential for self-defeating behavior in the domain of health, and have given reason for pessimism about the potential for health behavior change. We highlight that the main reason for this gloomy picture is that industrialized living environments are structured so that we are inundated with immediate behavioral contingencies that impel unhealthy behavior, and subtly but insidiously punish healthy behavior. Humans have the capacity to overcome these immediate contingencies if they have sufficient resources to do so, but will always be fighting an uphill battle in the presence of unfavorable environmental structure. This does not have to be the case. Environments could very well be structured in order to facilitate healthy choices (or at least not punish them), and to dampen risky behavioral tendencies.

In fact, this has been the promise of the ecological approach to health behavior change (Sallis & Owen, 2002).

Likewise, it is possible that products we use could be designed with our temporal biases in mind. Consider the case of contact lenses. In the past, one would be given a single set of conventional daily wear (CD) contact lenses that one was required to clean every night to reduce the risk of eye infection and other complications. This was a difficult task to maintain, and many of us would “cheat” by simply throwing the lenses in the saline solution without using the daily cleaner. At first this would be an occasional guilty pleasure (avoiding the minor inconvenience of adding another activity to the bedtime routine), but soon we would go days or maybe even a week without cleaning the lenses. This behavior pattern, unfortunately, increases the chance of getting an eye infection or other unsavory medical repercussions (Nanson et al., 1994). In other words, daily cleaning of CD lenses is one of those common behaviors that involves just enough cost at the time of performance to de-motivate making the choice that ultimately confers protection from disease.

That was the 1980s. In the 1990s, the contact lens industry realized that as long as lenses could be produced cheaply enough, you could actually get people to behave in ways that increase ocular health and pay more money for doing it. Soon, daily disposable contact lenses were unleashed onto the market. These individually packaged lenses are simply disposed of at the end of the day, and therefore no cleaning or rinsing is required. In fact, if you wanted to be a frugal and save your daily wear lenses for several days (the unhealthy choice) in order to save money in the long run, you would have to commit yourself to cleaning them every night or at least soaking them—not that difficult, but less convenient than simply throwing them away and opening a fresh, new pack the next morning. In essence, the industry has managed to market a new version of an old product that impels people to make healthy choices with great consistency. How did they accomplish it? Simply by altering the contingency structure associated with the healthy choice. By redesigning their product, healthy ways of using it became associated with a relatively more favorable set of immediate contingencies: increased convenience, reduced effort, and reduced time cost. Essentially, the contact lens industry performed psychological judo on the contact lens wearers of the world—our natural hyper-responsivity to immediate contingencies was used to develop and market a product that would improve our ocular health, yet cost us more money in the long run.

In addition to altering the products we use for the sake of contingency structure, we can also alter the environment in which we live toward the same end. With an epistemic foundation clearly allied with the work of Kurt Lewin (1935, 1936), ecological approaches to health involve structuring the environment so that there are fewer barriers (read: negative immediate contingencies) associated with making choices to pursue healthy lifestyles (Sallis & Owen, 2002). Interestingly, the barriers construct from the Health Belief Model is a consistently strong predictor of health behavior (Janz & Becker, 1984), giving a nod to the importance of ecological factors even on the level of individual behavior.

TST is not a model of individual behavior that dismisses environmental and social variables as exogenous; it provides a heuristic framework for organizing transactions among the person and the environment. This, of course, is not an entirely new enterprise. Albert Bandura, Martin Fishbein, Icek Ajzen, and Julian Rotter, among others, long ago identified the importance of outcome expectancies and values. Bandura, in particular, highlighted the notion of reciprocal determinism and the interactions among person and environment (Bandura, 1977, 1986). TST adds a temporal dimension to understanding perceptions of contingencies and values, and describes specific ways in which person and environment interact to produce behavioral patterns that are adaptive or maladaptive. As such, TST provides a novel and complementary theoretical frame to existing theories of health behavior.

Community and population-level intervention: Contingency structure and behavioral ecology

As a theory, TST provides a systematic way of thinking about the interface between the person and the environment. Specifically, TST would suggest that policy-level interventions are ideally suited to the task of changing immediate behavioral contingencies for both health risk and health protective behaviors. For example, public and workplace smoking bans serve to alter the immediate consequences of the decision to smoke. Under such policy interventions, the choice to light up a cigarette becomes associated with inconvenience, and potentially even discomfort: in order to make the unhealthy choice a smoker must endure the inconvenience of leaving the building and, in colder climates, enduring sub-zero temperatures outdoors. There is also a time cost associated with this behavioral choice that would not exist if one were able to simply light up at one's desk while working. The efficacy of workplace smoking bans for encouraging cessation and reducing consumption of tobacco among those who continue to smoke (e.g., Fichtenberg & Glantz, 2002) attests to their utility in changing behavior through simple alteration of the environment, such that unhealthy behavior is supplied with less favorable immediate contingencies. With respect to health protective behaviors, policy can also enhance positive, immediate behavioral contingencies for large segments of the population. Indeed, the ecological health literature has demonstrated that enhanced accessibility and removal of barriers can result in increased participation in physical activity (Booth et al., 2001; Frank, Anderson, & Schmid, 2004; Saelens, Sallis, & Frank, 2003; Sallis, Bauman, & Pratt, 1998).

In terms of mechanism, we suggest that a policy-level intervention will be successful to the extent it meaningfully alters the immediate contingencies for healthy and unhealthy behavior, rendering self-defeating behavior more difficult, and health promoting behavior more facile. In the same way, economic and social systems also serve to influence environments and the behavioral contingencies supplied by them. Deliberate or incidental, the characteristics of each socio-economic system has the potential to shape the likelihood of healthy or unhealthy

behavioral practices. This may, in part, explain the vast differences in rates of healthy and unhealthy behavioral practices (and associated rates of chronic illness) in different countries around the world (Steptoe et al., 2002; World Health Organization, 2002).

Population-based health education interventions can also be effective through altering social norms around behavior, thereby manufacturing new social contingencies for engaging in healthy and unhealthy behaviors. Culturally determined social norms and social sanctions all may influence behavior through alteration of immediate contingencies of the choice. Indeed there is much evidence already gathered to attest to the influence of local norms and peer groups on behavior of children, adolescents and adults (Harris, 1995; Romer, 2003).

Finally, public policy interventions can be used creatively to heighten contingency salience, or supply cues to action. Graphic warning labels on cigarette packaging and strategically placed signage to encourage stair use are both examples of this approach. In fact, these relatively light-handed environmental interventions yield surprisingly promising effects (Boutelle, Jeffery, Murray, & Schmitz, 2001; Brownell, Stunkard, & Albaum, 1980; Fong et al., 2002; Hammond, Fong, Borland, Cummings, McNeill, & Driezen, 2007; Hammond, Fong, McDonald, Brown & Cameron, 2004; Hammond, Fong, McDonald, Cameron, & Brown, 2003; Hammond, Fong, McNeill, Borland, & Cummings 2006), perhaps due to their effective heightening of contingency salience at crucial choice points.

In short, within the TST framework there is a close link between the notion of temporal contingencies and policy level intervention, socio-economic conditions, environment structure, social norms, and health behavior. Some ecological intervention strategies have been used, but what has been lacking is an integrative model that connects knowledge about the psychology of the individual to the ambient characteristics of the environment.

Individual-level intervention: Motivation, affect, and self-regulatory capacity

An individual's behavior is influenced by their own beliefs and values, and there is ample evidence that both can be changed through effortful intervention strategies (Glanz, Rimer, & Lewis, 2002). Further, some preliminary evidence suggests that interventions designed to enhance the salience of connections between present behavior and later outcomes, and to influence temporal valuations is strongly motivating for health protective behavior. Such interventions may produce stronger and longer-lasting behavioral effects than standard cognitive behavioral interventions or no treatment (Hall & Fong, 2003; 2004). Additional work is being conducted to extend behavioral interventions of this nature to other domains, including diabetes management, dietary choice, addictions and treatment adherence. Many other applications exist in and outside of the field of behavioral health.

TST provides the framework for understanding the role of anticipated emotions as agents of motivation in behavior change. According to regret theory

(Bell, 1982; Loomes & Sugden, 1982, 1987), the anticipation that one will regret some present action (or lack of some action) will create the motivation for changing one's behavior. The experience of anticipatory regret by its very nature is an indication that the individual has recognized the linkage between present behavior and future outcome, or in the language of TST, beliefs about connectedness have been engaged. The motivation to avoid the regret by changing that future outcome leads to the formulation of intentions to change present behavior to avoid future regret. As one example of the role of anticipatory regret in the formation of intentions, Fong et al. (2004) analyzed data from the International Tobacco Control Policy Evaluation Project's Four Country Survey (ITC Four Country Survey), which is a large-scale longitudinal survey of nationally representative samples of adult smokers from four countries: Canada, United States, United Kingdom, and Australia. In these studies, it was found that experienced regret about smoking initiation was significantly predictive of intentions to quit.

Negative emotional reactions can themselves represent anticipated outcomes for behavior and may motivate behavior in ways that are similar to other kinds of anticipated outcomes. For example, in a recent study, Chapman and Coups (2006) found that both experienced and *anticipated* negative emotions motivated health protective behavior—in this case, influenza vaccination—in a sample of university employees. Strength of belief that one would experience these negative emotions if vaccination were not undertaken and flu was contracted were stronger predictors of subsequent vaccination behavior than initial perceptions of risk for illness. When considering negative emotional states as a form of negative consequence in the emotional domain, these findings are entirely consistent with TST. That is, beliefs about future emotional contingencies for present behavior (“I will be consumed by regret *in the future* if I do/don't engage in behavior X *now*”) represent a special form of expected outcome for behavior. Through the lens of TST, these data suggest that beliefs about emotional contingencies (i.e., worry, regret) are motivating in a way directly analogous to beliefs about material contingencies (i.e., experience of illness, loss of function). Although Chapman and Coups' data suggest that although anticipated emotions are not perfectly calibrated with actual experienced emotions later in time, such anticipated emotions nonetheless are influential on health protective behavior. If anticipated negative emotional states are causally related to health behavior, interventions that enhance anticipation of future negative emotional consequences of a course of action (and connections of present behavior to these consequences) might be motivating for health protective behavior in the same way that other behavioral contingencies are (e.g., actual adverse health outcomes). Interventions that successfully import anticipated negative emotionality into deliberations about behavior should be likely to enhance healthy behavioral trajectories from this perspective (Abraham & Sheeran, 2004).

One individual-level variable that would seem difficult to modify is self-regulatory capacity. However, there may be some promise for both pharmacologic and non-pharmacologic means of boosting self-regulatory capacity. For

example, recent studies have suggested that regular cardiovascular exercise can help to mitigate age-related decline in executive function normally observed in older adults (Colcombe et al., 2004; Cotman & Berchtold, 2002). It has yet to be demonstrated that these effects are generalized to younger adults, but the possibility of “better chemistry through living” remains an exciting possibility (i.e., would dietary self-restraint become easier if aerobic exercise were used to boost self-regulatory capacity? Would running help ex-smokers resist the temptations to smoke again?; Marcus et al., 2005; Ussher, West, McEwen, Taylor, & Steptoe, 2003). These and other ways to boost self-regulatory capacity remain only lightly explored, and TST provides a framework for both posing research questions and selecting methodologies capable of answering them.

On the individual level, assessment of self-regulatory abilities may become an important part of the tailoring process for individual behavior change interventions. For example, individuals assessed to have poor executive function might be especially in need of environmental restructuring and social reinforcement to facilitate change, and lower expectations for change may be indicated. Likewise, such individuals might be especially in need of strategies for augmenting their existing self-regulatory abilities, and less in need of information regarding expected outcomes of behavior. This approach to assessment (both of self-regulatory abilities and impeding environmental factors) could contribute meaningfully to individually-tailored behavior change efforts for smokers, obese individuals, substance abusers, and those suffering from chronic illness, to name a few. Likewise, it is possible that for all individuals, motivation enhancement (Rollnick & Miller, 1995) coupled with environmental restructuring may have a synergistic and facilitative effect on health behavior change. Future research should examine these possibilities.

Conclusion

We have argued that healthy behavior patterns require active self-regulation, and that self-regulatory abilities must be modeled explicitly in any theoretical framework that aspires to explain health behavior. Research from the neurosciences suggests a central role for the PFC and ACC in the effortful regulation of behavior, particularly when that behavior is counter to environmental pull or instinctual drive. We have argued here and elsewhere (Fong & Hall, 2003; Hall et al., 2007) that health behaviors clearly fall into this category. To be sure, successful self-regulation requires motivation, and a temporally sensitive variant of the expectancy-value approach is a necessary and sufficient framework for understanding the motivational sphere of influences on human behavior. Motivational influences, however, may represent only part of the story. According to TST, the influence of intentions on behavior is moderated by self-regulatory capacity and behavioral prepotency, each of which also have direct effects on health behavior vis-à-vis ambient temporal contingencies supplied by the ecological context.

The question could legitimately be asked, “Do we need a new model of health behavior?” Indeed, many have argued that the field of behavioral health is over-run with models, and that integration is of more import than invention. However, there are several reasons why TST provides an important addition to the existing literature. First, even the most prominent and well-researched models of health behavior leave relatively large amounts of variance in health behavior unexplained (Sutton, 1998; Webb & Sheeran, 2006). Second, few models of health behavior attempt explicit integration of biological self-regulatory influences, despite their apparent relevance. Third, current research on temporal influences on human behavior—to its credit—has grown out of a number of fields, including economics, the neurosciences, medicine, and virtually every area of psychology (see Loewenstein et al., 2003), and organization of findings within a coherent theoretical framework is potentially useful in the domain of health behavior.

It is important to emphasize that temporal factors of the nature outlined here may figure prominently in all instances of self-defeating behavior (health-related or not). Indeed, one might argue that most behaviors that are colloquially referred to as “self-defeating” share the characteristic discontinuity of valence between immediate and non-immediate behavioral contingencies. Maladaptive emotional responses (e.g., Davidson, 2000), relationship patterns (e.g., Carstensen, Isaacowitz, & Charles, 1999; Lang & Carstensen, 2002), delinquent behavioral tendencies (e.g., Anderson, Bechara, Damasio, Tranel, & Damasio, 1999; Damasio, 2000), addictive behaviors (Steele & Josephs, 1990) and imprudent spending habits (Camerer, Loewenstein, & Prelec, in press) are just a few examples of phenomena that could be readily explained by application of TST principles. Health behavior is particularly interesting though, in that it constitutes perhaps the single most pervasive and insidiously lethal class of self-defeating behavior. For this reason alone, it is deserving of special attention.

As a theoretical framework, TST allows for explicit and systematic integration of self-regulatory, motivational, and ecological factors in a way that is not accomplished by existing models. Moreover, TST incorporates explicit reference to temporal factors in explaining behavior; as argued earlier these must be considered when behavioral contingencies are dispersed over time, as is apparently the case with health behaviors. As such, TST should serve an important heuristic function for researchers seeking to understand the relationship between humans, ecological contexts, and behavior patterns over time. As more is discovered about the mechanics of self-regulation and human responsiveness to environmental contexts, additional precision will be gained with the concepts introduced. In the end, understanding temporal dimensions of behavior is likely to carry significant explanatory power for understanding self-defeating tendencies, particularly those that occur with alarming frequency in the domain of behavioral health.

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Notes

- [1] This is changing in some parts of the world where norms against smoking are developing and public smoking bans are being implemented, effectively changing the valence of immediate contingencies associated with making the choice to light up a cigarette.
- [2] From this perspective, the notions of fatigue and energy may, in fact, be considered epiphenomenal.

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