Executive function moderates the intention-behavior link for physical activity and dietary behavior

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Executive function moderates the intention-behavior link for physical activity and dietary behavior

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Abstract
Dominant theories of health behavior posit that social-cognitive and conative variables are sufficient to explain health behavior tendencies. The current studies challenge this assumption in two ways: (1) by demonstrating that unique variance in health protective behavior is predictable by knowing about individual differences in executive functioning, and (2) by demonstrating that executive function moderates the association between intention and behavior. In Studies 1 and 2, participants completed a computer-based task of executive function (Go/NoGo task) and articulated 1-week behavioral intentions for physical activity (Study 1) and dietary behavior (Study 2). Hierarchical regression analyses revealed that executive function predicts unique variance in both behaviors, and strongly moderates the association between behavioral intention and behavioral performance. Together behavioral intention and executive function explain more variance in health protective behavior than ‘rational actor’ models that have been widely adopted and disseminated.

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

Introduction
Human beings in industrialized nations perform health protective behaviors with remarkable inconsistency. Of those who enroll in structured exercise programs,
on average only 50% are still exercising after six months (Dishman, 1991); fewer than 25% of people who start dieting are still dieting—even to a moderate degree—at 12-month follow-up (e.g., Dansinger, Gleason, Griffith, Selker, & Schaefer, 2004); fewer than 50% of patients take their medication with the required frequency and/or dosage to achieve the desired therapeutic effects (Meichenbaum & Turk, 1987); only about 25–50% of people who quit smoking manage to remain abstinent at 12 months (Curry & McBride, 1994), although this number increases significantly when complemented by environmental smoking bans (Eriksen & Gottlieb, 1998; Moskowitz, Lin, & Hudes, 2000). It could be argued that the phenomenon most deserving of explanation in the field of behavioral health is the remarkable consistency of unhealthy behavior, and the ephemeral nature of attempts to maintain health protective behaviors.

**Dominant models of individual health behavior**

Models of individual health behavior have been the most influential models in all of the behavioral health sciences (Glanz, Rimer, & Lewis, 2002). Two of the most widely cited social-cognitive models of health behavior are the Theory of Reasoned Action (TRA; Fishbein, 1967) and its extension, the Theory of Planned Behavior (TPB; Ajzen & Madden, 1986). Briefly, the TRA posits that behavior is most proximally determined by behavioral intention, such that conscious intention to perform a behavior is the strongest—and only—direct determinant of behavioral performance. Behavioral intention, in turn, is a function of attitudes toward the behavior and subjective impressions regarding the normativeness of the behavior. Attitudes and subjective norms are themselves determined by beliefs about likely outcomes of the behavior (i.e., behavioral beliefs), and the likely approval of significant others (i.e., normative beliefs). The TPB added one additional construct that was thought to affect behavior directly and indirectly through intention: perceived behavioral control.

This addition constituted an initial challenge to the exclusivity of intention for predicting behavior. The argument was that intention cannot be a strong determinant of behavior under conditions where the behavior is not entirely under the volitional control of the individual (i.e., intentions to perform an un-performable behavior will not be predictive of actual performance). This was a valid critique, and one that is sensible based on the fact that the TRA was originally devised with the modest goal of predicting voting behavior (Fishbein, 1967) which is largely unaffected by controllability factors, at least in democratic societies. Many health behaviors are affected by perceptions of controllability, and therefore the inclusion of the construct in the TPB makes intuitive sense. Empirical support for the incremental value of adding perceived behavioral control to the model has been demonstrated, but not always with high consistency (Armitage & Conner, 2001; Terry & O’Leary, 1995).

There is no doubt that the TRA and the TPB have been enormously influential, particularly in the field of health (for a review see Godin & Kok, 1996). The notion that behavior is primarily a function of proximal intention
has been an enormously productive idea and it, in fact, has a great deal of empirical support. For instance, Sheeran (2002) conducted a meta-analysis of 10 meta-analyses comprising 422 correlational studies describing intention-behavior relationships documented in the extant social-psychological literature. From this analysis he concluded that intentions account for approximately 28% of the variance in behavior, corresponding with a large effect based on Cohen's (1992) conventions for quantifying effect size. As such, enthusiasm for social-cognitive theories of health behavior—and for the predictive primacy of behavioral intention—has been largely warranted, and the popularity of decision-theoretic models has remained strong.

However, questions have emerged concerning two major facets of the intention construct: (1) ‘to what extent are intentions causally related to behavior?,’ and (2) ‘to what extent do other factors moderate the intention behavior relationship?’ In an investigation of the causal status of intention-behavior relations, Webb and Sheeran (2006) conducted a meta-analyses of experimental studies tracking the causal influence of intention change on behavior change. Aggregating across many different variants of behavior, they found that intervention-induced medium to large changes in intention resulted in small to medium changes in behavior. They concluded from their analysis that the causal effect of intention on behavior is overestimated by the extant correlational studies in the literature. Their analysis also indicated that intention-behavior relationships are moderated by several important factors, including perceived and actual controllability of the behavior itself. These findings, at minimum, suggest that intention-behavior relations deserve a closer analysis than might be suggested by existing health behavior theories.

Conceptualizing health behavior

Are health protective behaviors better conceptualized as problems of decision-making or as problems of self-regulation? The answer may depend on how we view the time course of the contingencies associated with health behaviors. Decision-making models are most appropriate when costs and benefits fall along a comparable temporal plane. This allows for consideration and choice based on the balance of negatively and positively valenced outcomes that are salient at the time of decision-making. To the extent that costs and benefits are confounded with proximity, however, a self-regulatory framework would become more appropriate, and individual differences in self-regulatory competence should influence behavioral performance (Hall & Fong, 2006). In effect, this would take models of health behavior outside the reach of rational choice, and place them squarely within the explanatory domain of self-regulation models.

Biologically-imbued self-regulatory abilities

With contemporary roots in social learning theory (Bandura, 1986; Mischel, Shoda, & Rodriguez, 1989), self-regulatory approaches to understanding health behavior have been the subject of increasing attention
To date, researchers have been primarily concerned with social-cognitive facets of self-regulation (e.g., furnishing implementation intentions, goal-setting, self-monitoring; Gollwitzer, 1999; Oettingen, Pak, & Schnetter, 2001; Sheeran & Orbell, 2000). Few studies have directly examined the biological basis for such cognitive operations as applied to the task of explaining health behavior tendencies. Recent studies have provided evidence to suggest that neurocognitive factors may indeed be implicated in patterns of health behavior over the lifespan (Deary, Whiteman, Starr, Whalley, & Fox, 2004; Gottfredson, 2004; Gottfredson & Deary, 2004; Hart et al., 2003), and that executive functions may be especially central (Hall, Elias, & Crossley, 2006).

Executive functions are those operations of the brain that enable effortful, or ‘top-down’ control of behavior (Norman & Shallice, 1986). Specific functions subsumed within this emergent construct are suspension of prepotent responses to stimuli, planning, error detection, and execution of novel behaviors in-context. Executive functions have traditionally been associated with the operation of the human frontal lobes and specifically the prefrontal areas (Fuster, 1997; Gazzaniga, Ivry, & Mangun, 1998; Koechlin, Ody, & Kouneiher, 2003), but also appear to be fundamentally connected to the operation of the anterior cingulate cortex (Paus, 2001). A number of different tests of executive function have been used in the research literature, most commonly the Wisconsin Card Sorting Task, the Tower of London task, the Stroop task and the Go/NoGo task. Each of these tasks is thought to tap one or more component of executive function, with the former tests tapping response shifting and planning, and the latter tapping something closer akin to interference and response regulation.

Given their relevance for effortful self-regulation, it seems reasonable to posit that executive functions would be associated with consistent performance of health behaviors that require endurance of inconvenience, discomfort or other negative immediate contingencies. Moreover, it could reasonably be argued that executive functions should moderate the association between intention and action for health protective behaviors.

The current studies

Most of the dominant models of individual health behavior reflect the assumption that social-cognitive variables are sufficient to explain health behavior. However, because the valence (positive vs. negative) and proximity (immediate vs. non-immediate) of behavioral contingencies are confounded for health protective behaviors, self-regulatory abilities should explain additional variance in these behaviors over and above behavioral intention. Moreover, given what is already known about executive functions and the effortful regulation of intentional behavior (Fuster, 1997; Paus, 2001), individual differences in executive function should moderate the association between behavioral intention and behavioral performance. That is, individuals with strong executive function
should demonstrate stronger associations between intention and behavior than those with weak executive function, because of the facilitative role of executive functions in effortful self-control. In Studies 1 and 2 we test these hypotheses for two prototypical health protective behaviors: physical activity and healthy dietary choice.

**Study 1**

*Method*

**Participants.** A sample of 64 undergraduates (Table I) attended two laboratory sessions spaced one week apart. In the first session, participants completed a computer-administered Go/NoGo Task, and filled out a questionnaire package containing the study measures. At the end of the session participants were scheduled to return in exactly seven days for a second session wherein they again filled out the same questionnaire package, excluding demographics.

**Measures**

**Executive function.** A Go/NoGo computer task was used to measure individual differences in executive function. This measure requires individuals to actively regulate responses to presented stimuli and either initiate responses quickly or inhibit response effortfully. The executive function construct is multi-dimensional (Miyake et al., 2000), and Go/NoGo measures predominantly tap one facet of executive function that may be particularly pertinent to behavioral self-regulation: the ability to suspend prepotent responses to external cues. Functional imaging studies have documented associations between Go/NoGo performance and activation in the prefrontal and anterior cingulate regions of the brain; both structures have been implicated in behavioral self-regulation in humans (Hester, Fassbender, & Garavan, 2004; Watanabe et al., 2002).

![](https://example.com/table1.png)

**Table I. Study 1 demographic variables.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>19.0</td>
<td>2.50</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>66.33</td>
<td>3.49</td>
</tr>
<tr>
<td>Weight</td>
<td>137.21</td>
<td>22.85</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td>23.1%</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td>73.9%</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aboriginal</td>
<td></td>
<td>3.1%</td>
</tr>
<tr>
<td>Asian</td>
<td></td>
<td>12.3%</td>
</tr>
<tr>
<td>Caucasian</td>
<td></td>
<td>73.8%</td>
</tr>
<tr>
<td>Middle Eastern</td>
<td></td>
<td>1.5%</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>4.6%</td>
</tr>
</tbody>
</table>

Note: \( N = 64 \).
For the Go/NoGo task, participants were seated in front of a computer, and were given the following instructions by the experimenter: ‘For this task, you will be presented with a series of upper case or lower case letters on the screen (presented individually, one after another with a fixation cross in between). Each time you see a LOWER CASE letter, press the ‘enter’ key as quickly as you can. Each time you see an UPPER CASE letter, refrain from pressing the ‘enter’ key. Do this as quickly as you can – both speed and accuracy count.’ Participants completed a preliminary block of 12 practice trials (with equal numbers of upper and lower case letters) after which the experimenter re-emphasized the importance of speed and accuracy, and began the test trails. The test phase consisted of eight blocks of 60 trials. In half of the blocks lower case letters predominate (‘Go’ phase blocks) and in half of the blocks upper case letters predominate (‘NoGo’ phase blocks). The order of blocks was counterbalanced across participants. Reaction times were computed for correct responses only to lower case letters and were computed separately for Go and NoGo phase blocks. Go and NoGo phase reaction times were moderately correlated ($r = 0.602; p < 0.001$) and were therefore combined into a single overall reaction time index for the sake of parsimony.

**Physical activity.** Participants were asked to report the number of hours they had engaged in vigorous physical activity over the past week to the nearest half hour, using examples of behavioral criteria for vigorous intensity activities (Smith, 1994). This self-report measure was derived from the interview-based Stanford 7-Day recall (Sallis et al., 1985) and the version used here correlated $r = 0.60 (p < 0.001)$ with tri-axial accelerometer-assessed physical activity over the course of a 7-day interval in healthy young adults in this age range (Hall, 2006). In addition, this measure has proven sensitive to behavioral intervention effects (e.g., Hall & Fong, 2003).

**Behavioral intention.** Behavioral intention was assessed by adjusting the wording of the self-report physical activity measure to refer to activity intended over the next week. This was accomplished by substituting the word ‘past week’ with ‘next week.’ The close match between the structure of the measure of intention and the measure of behavior follows recommendations for preservation of scale correspondence (Courneya, 1994) and therefore represents the most stringent test of intention-behavior associations. The choice of a brief (one-week) bounded time frame also maximizes the applicability of the measure of behavioral intention to the task of actual behavioral prediction.

**Results and discussion**

Intercorrelations among Study 1 variables are presented in Table II. Consistent with our hypotheses, multiple regression analyses indicated that both behavioral intention ($\beta = 0.668; p < 0.001$) and Go/NoGo reaction times ($\beta = -0.191; p = 0.058$) each predicted unique variance in physical activity after controlling for
Table II. Means, standard deviations, and intercorrelations of study 1 variables.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Age</td>
<td>1.00</td>
<td>0.082</td>
<td>0.405**</td>
<td>-0.157</td>
<td>-0.148</td>
<td>-0.168</td>
<td>-0.170</td>
<td>-0.023</td>
</tr>
<tr>
<td>2</td>
<td>Gender</td>
<td>0.082</td>
<td>1.00</td>
<td>0.283*</td>
<td>-0.291</td>
<td>-0.179</td>
<td>-0.190</td>
<td>-0.167</td>
<td>-0.016</td>
</tr>
<tr>
<td>3</td>
<td>Education</td>
<td>0.405**</td>
<td>0.283*</td>
<td>1.00</td>
<td>-0.119</td>
<td>-0.012</td>
<td>-0.141</td>
<td>-0.191</td>
<td>-0.097</td>
</tr>
<tr>
<td>4</td>
<td>PAR T1</td>
<td>-0.157</td>
<td>-0.291*</td>
<td>-0.119</td>
<td>1.00</td>
<td>0.769**</td>
<td>0.725**</td>
<td>-0.030</td>
<td>-0.339**</td>
</tr>
<tr>
<td>5</td>
<td>Intention</td>
<td>-0.148</td>
<td>-0.179</td>
<td>-0.012</td>
<td>0.769**</td>
<td>1.00</td>
<td>0.685**</td>
<td>-0.028</td>
<td>-0.104</td>
</tr>
<tr>
<td>6</td>
<td>PAR T2</td>
<td>-0.168</td>
<td>-0.190</td>
<td>-0.141</td>
<td>0.725**</td>
<td>0.685**</td>
<td>1.00</td>
<td>-0.079</td>
<td>-0.316*</td>
</tr>
<tr>
<td>7</td>
<td>RT (G)</td>
<td>-0.170</td>
<td>-0.167</td>
<td>-0.191</td>
<td>-0.030</td>
<td>-0.028</td>
<td>-0.079</td>
<td>1.00</td>
<td>0.602**</td>
</tr>
<tr>
<td>8</td>
<td>RT (NG)</td>
<td>-0.023</td>
<td>-0.016</td>
<td>-0.097</td>
<td>-0.339**</td>
<td>-0.104</td>
<td>-0.316*</td>
<td>0.602**</td>
<td>1.00</td>
</tr>
<tr>
<td>9</td>
<td>RT</td>
<td>-0.126</td>
<td>-0.122</td>
<td>-0.172</td>
<td>-0.166</td>
<td>-0.064</td>
<td>-0.189</td>
<td>0.944**</td>
<td>0.833**</td>
</tr>
</tbody>
</table>

Notes: PAR = Physical Activity Recall; RT(G) = reaction time, “Go” trials only; RT(NG) = reaction time, “NoGo” trials only; RT = overall reaction time. N= 64. *p < 0.05; **p < 0.01 (2-tailed).
demographic variables (age, gender, years of education). Importantly, however, analyses also revealed a significant two-way interaction between Go/NoGo reaction times and behavioral intention, predicting physical activity ($\beta = -0.282; p = 0.004$; Table III). Moderational analyses were conducted in accordance with Aiken and West (1991) by forming high and low executive function groups (overall sample $M$ Go/Nogo score $\pm 1$ SD) and testing the significance of the regression slope predicting behavior from intention for each group separately. As hypothesized, the predictive power of behavioral intention for physical activity was significant for those with strong executive functioning ($\beta = 0.974; t = 8.03; p < 0.001$). Behavioral intention was also a significant predictor of behavior for those with weak executive function, but notably less substantial ($\beta = 0.305; t = 2.19; p = 0.032$). Regression slopes are presented for each group separately in Figure 1.

The two-way interaction between intention and executive function remained after controlling for the potentially confounding effects of past behavior, albeit somewhat attenuated ($\beta = -0.208; p = 0.073$). The model as a whole accounted for 61.1% of the variance in physical activity ($R^2 = 0.611; p < 0.001$) with past behavior included. A model including only the independent and interactive effects of behavioral intention and executive function still accounted for 58.5% of the variance in dietary behavior ($R^2 = 0.585; p < 0.001$).

**Study 2**

In Study 2, we used an identical design to replicate the effects observed in Study 1 by examining a second variant of health protective behavior: healthy dietary choice. Again, we had all participants ($N = 121$; see Table IV) attend two laboratory sessions spaced one week apart. In the first session, participants completed a brief measure of fruit and vegetable consumption—the NCI Fruit and Vegetable Screener—as an index of healthy dietary choice (Thompson et al., 2004). Participants also completed an adapted version designed by altering the

<p>| Table III. Hierarchical regression analyses: Executive function as a moderator of the relation between behavioral intention and physical activity. |</p>
<table>
<thead>
<tr>
<th>Variable</th>
<th>$\beta$</th>
<th>$F$</th>
<th>$\Delta R^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>$-0.138$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>$-0.148$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>$-0.042$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INT</td>
<td>$0.668$</td>
<td>$11.187$</td>
<td>$0.463$</td>
<td>$0.000$</td>
</tr>
<tr>
<td>EXEC</td>
<td>$-0.191$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INT $\times$ EXEC</td>
<td>$-0.282$</td>
<td>$12.229$</td>
<td>$0.072$</td>
<td>$0.004$</td>
</tr>
</tbody>
</table>

Notes: Dependent = physical activity; INT = behavioral intention; EXEC = executive functioning; overall $R^2 = 0.590$. 

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wording of the same scale items to assess intentions for the next week. Participants completed the same version of the Go/NoGo task described in Study 1; again both Go and NoGo phase reaction times were correlated ($r = 0.696; p < 0.001$), and were combined into a single omnibus reaction time measure. In the second session participants again completed the dietary choice
measure assessing consumption of fruit and vegetable intake over the course of the intervening week.

Results and discussion

Intercorrelations among Study 2 variables are presented in Table V. Multiple regression analyses confirmed that individual differences in executive function again predicted health behavior tendencies. Reaction times on the Go/NoGo task ($\beta = -0.137; p = 0.030$) and behavioral intentions ($\beta = 0.736; p < 0.001$) each predicted unique variance in dietary behavior after controlling for demographic variables.

Again, our analyses revealed a significant two-way interaction between executive function and behavioral intention, predicting healthy dietary choice ($\beta = -0.203; p = 0.001$; Table VI). Strong and weak executive function groups were formed (overall sample $M$ Go/NoGo score $\pm 1$ SD) and we then tested the significance of the regression slope predicting behavior from intention for each group separately. As hypothesized, the predictive power of behavioral intention for physical activity was significant for those with strong executive functioning ($\beta = 0.950; t = 11.12; p < 0.001$). Behavioral intention was also a significant predictor of behavior for those with weak executive function but, again, less substantial ($\beta = 0.652; t = 10.36; p < 0.001$). Regression slopes are presented for each group separately in Figure 2.

The interaction between intention and executive function remained after controlling for past behavior although slightly attenuated ($\beta = -0.171; p = 0.023$). The model as a whole accounted for 62.1% of the variance in dietary behavior ($R^2 = 0.621; p < 0.001$) with past behavior included. A model including only the independent and interactive effects of behavioral intention and executive function still accounted for 61.2% of the variance in dietary behavior ($R^2 = 0.612; p < 0.001$).

General discussion

Our findings challenge two assumptions held by dominant theories of individual health behavior: (1) that social-cognitive and motivational variables are sufficient to explain behavior, and (2) that the link between intention and behavior is uniform and universal. In Study 1, we tested the hypothesis that self-regulatory abilities would predict patterns of physical activity over the course of a week, and that they would moderate the association between intentions and behavior. We found support for both of these hypotheses. In Study 2, we found evidence that individual differences in executive function predicted unique variance in dietary behavior over and above behavioral intention alone, and strongly moderate the association between behavioral intention and behavioral performance. The proportion of variance accounted for by our model was large for both target behaviors selected. In fact, the proportion of variance explained solely by the independent and interactive effects of intention and executive function – 59% for
Table V. Means, standard deviations, and intercorrelations of Study 2 variables.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>5</th>
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<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Age</td>
<td>1.00</td>
<td>-0.108</td>
<td>0.446**</td>
<td>-0.010</td>
<td>-0.032</td>
<td>-0.001</td>
<td>0.056</td>
<td>0.027</td>
</tr>
<tr>
<td>2</td>
<td>Gender</td>
<td>-0.108</td>
<td>1.00</td>
<td>-0.019</td>
<td>0.003</td>
<td>0.074</td>
<td>0.068</td>
<td>-0.015</td>
<td>0.076</td>
</tr>
<tr>
<td>3</td>
<td>Education</td>
<td>0.446**</td>
<td>-0.019</td>
<td>1.00</td>
<td>0.100</td>
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<td>0.098</td>
<td>-0.173</td>
<td>-0.124</td>
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<tr>
<td>4</td>
<td>NCI T1</td>
<td>-0.010</td>
<td>0.003</td>
<td>0.100</td>
<td>1.00</td>
<td>0.752**</td>
<td>0.677**</td>
<td>-0.104</td>
<td>-0.179</td>
</tr>
<tr>
<td>5</td>
<td>Intention</td>
<td>-0.032</td>
<td>0.074</td>
<td>-0.029</td>
<td>0.752**</td>
<td>1.00</td>
<td>0.742**</td>
<td>-0.006</td>
<td>-0.077</td>
</tr>
<tr>
<td>6</td>
<td>NCI T2</td>
<td>-0.001</td>
<td>0.068</td>
<td>0.098</td>
<td>0.677**</td>
<td>0.742**</td>
<td>1.00</td>
<td>-0.169</td>
<td>-0.153</td>
</tr>
<tr>
<td>7</td>
<td>RT (G)</td>
<td>0.056</td>
<td>-0.015</td>
<td>-0.173</td>
<td>-0.104</td>
<td>-0.006</td>
<td>-0.169</td>
<td>1.00</td>
<td>0.696**</td>
</tr>
<tr>
<td>8</td>
<td>RT (NG)</td>
<td>0.027</td>
<td>0.076</td>
<td>-0.124</td>
<td>-0.179</td>
<td>-0.077</td>
<td>-0.153</td>
<td>0.696**</td>
<td>1.00</td>
</tr>
<tr>
<td>9</td>
<td>RT</td>
<td>0.050</td>
<td>0.016</td>
<td>-0.169</td>
<td>-0.138</td>
<td>-0.032</td>
<td>-0.176</td>
<td>0.967**</td>
<td>0.856**</td>
</tr>
</tbody>
</table>

M 22.24  1.78  4.98  6.58  7.64  6.23  403.42  477.29  642.07
SD 5.24   0.42   0.49   4.56   5.42   4.41   50.04   49.63  69.62

Notes: NCI = NCI Fruit & Vegetable screener; RT(G) = reaction time, “Go” trials only; RT(NG) = reaction time, “NoGo” trials only; RT = overall reaction time. N = 124. **p < 0.01 (2-tailed).
physical activity and 61% for dietary behavior – is almost double the variance in health behavior typically accounted for by the TPB and more than double that typically accounted for by the TRA (Sheeran, 2002; Sutton, 1998).

The finding that a novel psychological construct can explain significant variance in health behaviors over and above proximal TRA/TPB constructs is somewhat rare, and is significant in its own right. The only theoretically situated

Table VI. Hierarchical regression analyses: Executive function as a moderator of the relation between behavioral intention and dietary behavior.

<table>
<thead>
<tr>
<th>Variable</th>
<th>β</th>
<th>F</th>
<th>ΔR²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td></td>
<td>0.646</td>
<td>0.017</td>
<td>0.587</td>
</tr>
<tr>
<td>Age</td>
<td>-0.052</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>0.065</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>0.123</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td>31.188</td>
<td>0.565</td>
<td>0.000</td>
</tr>
<tr>
<td>INT</td>
<td>-0.137</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXEC</td>
<td>0.736</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 3</td>
<td></td>
<td>30.009</td>
<td>0.037</td>
<td>0.001</td>
</tr>
<tr>
<td>INT × EXEC</td>
<td>-0.203</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Dependent = fruit and vegetable intake; INT = behavioral intention; EXEC = executive functioning; overall R² = 0.619.

Figure 2. The relation between behavioral intention and healthy dietary choice for high and low executive function participants.
variables that typically predict unique variance in behavior over and above intention are perceived behavioral control and past behavior. In this study, we have statistically controlled for the effects of the latter. With respect to the former, one might reasonably ask: to what extent does perceived behavioral control represent accurate self-knowledge about one’s own self-regulatory abilities? This is an empirical question, and one that should be addressed by future research.

Of significance is the fact that individual differences in executive function predict health behavior performance even over relatively short periods of time (i.e., 7 days). The relative predictive power of executive function over longer time intervals has yet to be determined. It is possible, for example, that the effects of intention swamp effects of executive function over longer periods of time. On the other hand, it is possible that individual differences in executive function may explain proportionately even more variance in health protective behaviors when the latter are aggregated over longer periods of time (i.e., months or years). Again, this is an empirical question that should be addressed in future studies.

**Limitations**

Limitations of these studies include reliance on self-report measures of physical activity and dietary behavior, which may introduce recall biases. It could be argued, for example, that executive function and recall may rely on the same common source of abilities. Alternatively, one could suggest that self-report measures of health behavior may be subject to impression management efforts, which are also potentiated by the operation of the same areas of the brain implicated in executive function (Richeson et al., 2003). More objective measurement of behavioral criteria in future studies would help to address this issue.

Also, given that there is no experimental manipulation of the independent variables, some may call into question the causal relationship between the predictors and outcome. Indeed, some intriguing work has demonstrated that regular cardiovascular activity can actually cause changes in brain function – at least in older individuals– that may be specific to the prefrontal area (Colcombe et al., 2004; Cotman & Berchtold, 2002; Kramer et al., 2004) suggesting that the association between individual differences in executive function and physical activity could be bi-directional. As such, it is true that assumptions about causality must be tempered, particularly when interpreting the results of Study 1. However, in the current studies we used a prospective design (having measured the predictors at baseline and the behavior at one-week follow-up), and have controlled for past behavior in our statistical analyses, thus increasing our confidence in our presumptions about directionality.

These limitations notwithstanding, the present findings complement work of researchers exploring the functional neuroanatomy of inter-temporal choice (McClure, Laibson, Loewenstein, & Cohen, 2004), and are consistent with
classic conceptualizations of executive function (e.g., Fuster, 1997; Norman & Shallice, 1986). Most importantly, the predictive power of individual differences in executive function calls into question the exclusive primacy of behavioral intention for guiding health protective behavior. Indeed, there may be other facets of self-regulatory capacity that vary in state- and trait-like ways (Muraven & Baumeister, 2000), and these also must be considered in models that purport to explain behaviors that are associated with temporally dispersed costs and benefits.

**Conclusion**

By their very nature, health protective behaviors are associated with many benefits (e.g., health, appearance, mood), but also subtle costs (e.g., inconvenience, discomfort). Unfortunately, at the level of individual perception, costs occur at the time of performance while benefits occur hundreds of hours later, thereby necessitating significant behavioral self-regulation in order to maintain consistent performance over time (Hall & Fong, 2006). Studies 1 and 2 confirmed that individual differences in executive function prospectively predict health protective behavior tendencies over and above behavioral intention alone, and strongly moderate the link between intention and behavior. These findings suggest that models of health behavior should take a self-regulatory perspective by including both conative and biological determinants of health behavior performance.

Existing theoretical models have done a reasonable job of explaining the motivational end of the equation; what is missing is a more central focus on the phenomenon of self-regulation (Bandura, 1986; Carver & Scheier, 1998; Schwarzer, 2001), and an integration of the growing literature of temporal influences on health behavior (e.g., Loewenstein, Read, & Baumeister, 2003; Sanna & Chang, 2006). Although a significant literature already attests to the importance of self-regulatory *skills* for behavioral self-control (Mischel et al., 1989), consideration of self-regulatory *abilities* represents an important new avenue of scientific inquiry, particularly with reference to health behaviors that are future-oriented in nature.

**Future directions**

There has been increasing dissatisfaction with dominant social-cognitive models of health behavior (e.g., Noar & Zimmerman, 2005; Weinstein & Rothman, 2005), and a simultaneous call for increased focus on truly biopsychosocial approaches within the field of health psychology (Suls & Rothman, 2004). Here we have provided evidence that integration of biological elements into a social-cognitive framework may indeed be a fruitful direction for theorizing about health behavior. On an applied level, the present findings suggest that health promotion efforts should include motivation induction techniques coupled with efforts to
structure environments in such a way that immediate contingencies for health protective behaviors are more positive (or at least less negative), thereby reducing the demand on self-regulatory resources. Indeed this is the philosophy behind many ecological approaches to health promotion, many of which have shown a great deal of promise (Sallis & Owen, 2002). In the end, an appreciation of biologically-imbued capacities for self-regulation may lead us to a keener appreciation of the importance of environmental influences on human behavior.

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Notes

[1] Other models, like the Transtheoretical Model (TTM; Prochaska, DiClemente, & Norcross, 1992) have also emphasized the role of intentional behavior and deliberation over costs and benefits. Inspired by Janis and Mann’s (1977) conceptualization of health behavior as a series of behavioral choices, the followers of TTM have adopted the primacy of costs/benefit analyses for understanding transitions between stages of change (i.e., precontemplation, contemplation, action, maintenance), implying a high degree of deliberativeness and intentionality in human behavior in a manner surprisingly consistent with their social cognitive predecessors.

[2] Accuracy must be taken into account when computing reaction times for the Go/NoGo and similar measures of executive function. Quick response latencies on incorrect trials could indicate impulsive responding rather than strong executive functioning.

[3] This was a well-validated screening measure developed by the National Cancer Institute. In a large scale validation study, this measure correlated 0.50 to 0.80 with estimated true intake, and performed similarly to more time consuming food frequency questionnaires (Thompson et al., 2004).

[4] Zero-order correlations between predictor variables and measures of behavior do not attain statistical significance despite having significant Beta weights in the main regression analyses. This is partially because the tests of significance for the zero-order correlations presented in Tables II and V are 2-tailed, and partially because control variables are included in the regression analyses. Demographic variables absorb some error variance in the dependent measures allowing a greater proportion of variability to be predictable by knowing about intention, executive function and their interaction.

References


Executive function moderates intention-behavior link


