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BRIEF REPORT

Neurocognitive Influences on Health Behavior in a Community Sample

Peter A. Hall
University of Waterloo

Lorin J. Elias and Margaret Crossley
University of Saskatchewan

Context: Dominant models of individual health behavior omit biological variables entirely and are composed almost exclusively of social–cognitive and conative variables. Research from the neurosciences suggests a role for brain function in explaining behaviors that require active self-regulation for consistent performance. However, the association between brain function and health behavior is underexplored. *Objective*: To examine the predictive power of executive function for 2 health risk behaviors and 2 health protective behaviors in healthy adults. *Design*: A cross-sectional community sample (N = 216) of adults 20–100 years of age were administered a battery of neuropsychological tests and completed self-report questionnaires regarding their health practices. It was hypothesized that poor performance on neuropsychological tests tapping executive function would be associated with poor health behavior tendencies. *Results*: Errors on the Stroop task were positively associated with health risk behavior and negatively associated with health protective behavior after controlling for demographics, education, and IQ. *Conclusion*: Executive function is associated with health behavior tendencies. If the association is causal, explanatory models of individual health behavior should be revised to account for individual differences in biologically imbued self-regulatory abilities.

Keywords: health behavior, executive function, self-regulation, intelligence, chronic illness

Dominant models of individual health behavior comprise mostly—if not entirely—social–cognitive and conative variables. This holds true for the theory of reasoned action (Fishbein, 1967), the theory of planned behavior (Ajzen & Madden, 1986), the transtheoretical model (Prochaska, DiClemente, & Norcross, 1992), and the health belief model (Rosenstock, 1960).[1] However, decades of research from the fields of neuroscience and neuropsychology suggest that neurocognitive variables are strongly implicated in any behavior that requires effortful self-regulation over time (Fuster, 1997; Norman & Shallice, 1980). The striking omission of neurocognitive variables from models of individual health behavior is increasingly suspect, particularly in light of findings from several large prospective studies identifying an association between general cognitive function and mortality end points, particularly those end points that implicate behavioral mediators (e.g., cardiovascular diseases, diabetes, cancer, motor vehicle accidents; Deary, Whalley, & Starr, 2003; Hart et al., 2003).

Does health behavior performance constitute an example of "effortfully regulated" behavior? According to Temporal Contingency Theory (Hall & Fong, 2005), health maintaining behavior requires effortful regulation whenever there is a disjunction in valence between immediate and nonimmediate contingencies. That is, when behaviors are front end loaded with costs—even in the presence of long-term benefits—consistent performance requires effortful self-regulation. Likewise, when behaviors are front end loaded with benefits—but back end loaded with costs—abstinence requires effortful self-regulation. The former is the prototypical contingency structure of health protective behaviors (e.g., physical activity, healthy dietary choice), whereas the latter is the prototypical contingency structure for health risk behaviors (e.g., substance use, risky sexual behaviors; Hall & Fong, 2005; Hall, Fong, Epp, & Elias, 2005). As such, both performance of health protective behaviors and avoidance of health risk behaviors invoke the need for self-regulatory abilities and resources—the kind afforded by the function of brain structures, such as the prefrontal cortex, the anterior cingulate and associated neural systems (Fuster, 1997).

Past research has suggested that individual differences in health behavior patterns within the general population may be partially a function of motivation and partially a function of self-regulatory capacity (i.e., individual capacities to effortfully regulate behavior; Hall et al., 2005). Given that one important facet of executive function is the capacity to regulate one's own behavior (Fuster, 1997), individual differences in executive function may explain some individual differences in health behavior patterns observable in the general population. In this study, we tested this hypothesis by examining the association between performance on a cognitive task tapping executive function (the Stroop Neuropsychological Screening Test [SNST]; Trennery, Crosson, DeBoe, & Leber, 1989) and indicators of health risk behavior (smoking behavior,

Peter A. Hall, Faculty of Applied Health Sciences, University of Waterloo, Waterloo, Ontario, Canada; Lorin J. Elias and Margaret Crossley, Department of Psychology, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

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Correspondence concerning this article should be addressed to Peter A. Hall, Faculty of Applied Health Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada. E-mail: pahall@uwaterloo.ca

[1] The only clear exception to this general statement is Self-Efficacy Theory (Bandura, 1977), which allows for biological influences within the person component of the reciprocal determinism portion of the framework.

alcohol consumption) and health maintaining behavior (sleep habits, physical activity) in a community sample.

Method

Participants

The sample consisted of 217 adults recruited from the community between March 1995 and April 1998 for studies on normal aging processes and cognitive function (see Table 1). Mean age was 54.90 years (*SD* = 20.36), with a range spanning from 20 to 100 years. We recruited participants using posters placed in community settings (e.g., medical clinics, seniors' apartments, fitness centers, churches), newsletter ads, and presentations to community groups (e.g., choirs, social clubs). Participants were excluded if they (a) endorsed any questionnaire items on a self-report screening instrument indicating the presence of any neurological, psychiatric, or other medical or developmental conditions that could interfere significantly with higher brain functions or (b) indicated that they were currently taking any medications known to have psychotropic effects. All participants were screened for factors that might limit manual speed and dexterity (e.g., arthritis, residual effects of a hand injury), and those who showed evidence of these were also excluded.

Procedure

Participants were administered a standard battery of neuropsychological tests, experimental procedures (e.g., dual tasks), and self-report measures of health behavior tendencies. Although the makeup of the tasks changed over the data collection period, all versions of the protocol included the same self-report health behavior measures, the SNST, and the Peabody Picture Vocabulary Test—Revised (PPVT–R; Dunn & Dunn, 1981). Cognitive tests were administered by licensed psychologists or trained doctoral students in clinical psychology.

Measures

SNST. In the Stroop task, the examinee is presented with a card containing a series of color words presented in different color ink, and he or she is required to quickly name the color of the ink for each word while inhibiting the semantic meaning of the color word itself. As such, the Stroop task is a measure of interference caused by competing cognitive demands associated with naming the color of the ink in which the prepotent response is to read the color word itself. In support of the contention that Stroop task performance taps executive functions normally attributed to the frontal lobe, Perret (1974) demonstrated that scores were sensitive to localized brain damage, with poorer performance exhibited by patients with frontal damage than those with either temporal or posterior damage. The SNST is a fully standardized version of the Stroop procedure that has been validated as both a neuropsychological screening tool and a research instrument. Furthermore, the SNST has demonstrated impressive temporal stability, which supports its use as a measure of stable individual differences in executive function. The number of errors made by the examinee in the time allotted (120 s) is recorded, and this metric is recommended by the authors of the test as the most appropriate way of quantifying performance (Trennery et al., 1989).

PPVT–R. The PPVT–R was originally developed as a culture-free test of general cognitive function but has since become popular as a brief measure of IQ with relatively few verbal and motor response requirements of the examinee. In this test, examinees are presented with an array of standard drawings on a card and asked to indicate as quickly as possible the object indicated verbally by the tester. The PPVT–R has been used extensively in the research literature as a proxy for IQ under circumstances when a more comprehensive test cannot be administered (e.g., the Wechsler Adult Intelligence Scale or Stanford–Binet), and indeed scores on the PPVT–R correlate well with IQ scores, particularly with verbal IQ (Dunn & Dunn, 1981).

Health behavior. Given that the original questionnaire package was designed to be a brief survey to compliment the extensive battery of neuropsychological measures administered, health behaviors were assessed with either a single item (e.g., sleep difficulties [such as insomnia, excessive daytime sleeping, day/night reversals]: "Are you experiencing any difficulties with sleep?"; exercise: "How many times per week do you exercise [minimum 20 min]?") or a four-item screening inventory (CAGE Questionnaire for assessing problems with alcohol; Ewing, 1984). For smoking behavior, number of pack years smoked was calculated by the self-reported number of years smoked and the maximum number of packs per day smoked.

Table 1
Demographic Characteristics of Sample

Variable	*M*	*SD*	%
Age (years)	54.90	20.36	
Years of formal education	14.48	3.62	
Gender			
Men			53.9
Women			43.3
Ethnicity			
Caucasian			94.5
Aboriginal/Metis			1.4
Other			1.4

Note. *N* = 217.

Results

Means and standard deviations for neurocognitive and health behavior variables are presented by age group in Table 2. To test the hypothesis that executive function is associated with health behavior tendencies, we conducted multiple regression analyses using four health behaviors as the dependent variable in separate analyses: number of pack years smoked, problems with alcohol, sleep difficulties,[2] and exercise. Age,[3] gender, and years of formal education were entered as a block on the first step as control variables. Scores on the PPVT–R were entered on the second step as a measure of IQ. Lastly, errors on the Stroop (SNST) were entered on the final step. The crucial analysis, therefore, is the increment in variance explained with the addition of SNST performance on the final step.

For number of pack years smoked ($\beta = .564$; R^2 change = .291, $p < .001$; see Table 3), problems with alcohol ($\beta = .155$; R^2 change = .022, $p < .05$; see Table 4), and sleep difficulties ($\beta = .224$; R^2 change = .047, $p < .01$; see Table 5), SNST performance predicted a significant increment of the variability in health behavior over and above demographics, education, and IQ. The effects were

[2] Responses to the sleep item were given on a 5-point scale ranging from 1 (*not at all*) to 5 (*extremely*), and as such multiple regression analyses were deemed more appropriate than logistic regression (the latter would be appropriate if the response scale was simply "yes" versus "no").

[3] The inclusion of age as a control variable in subsequent analyses was necessitated by the possibility that age could confound the association between cognitive function and several health behaviors of interest (e.g., number of pack years smoked).

Table 2
Means (and Standard Deviations) for Neurocognitive and Health Behavior Variables by Age Group

Age group	n	SNST	PPVT–R	CAGE Questionnaire	No. of pack years smoked	Sleep difficulties	No. of days exercised per week
20–40	65	0.49 (0.81)	162.22 (9.41)	1.55 (2.23)	2.89 (4.47)	2.06 (1.17)	3.15 (2.01)
41–65	66	0.65 (1.03)	163.63 (9.39)	0.84 (1.66)	7.76 (13.17)	1.97 (1.01)	3.71 (3.24)
65+	85	1.19 (3.29)	163.27 (10.46)	0.31 (1.16)	12.04 (25.06)	1.85 (0.92)	4.15 (2.77)
Totals	216	0.81 (2.17)	163.06 (9.80)	0.86 (1.77)	7.96 (17.73)	1.95 (1.03)	3.71 (2.74)

Note. Total N for the sample is 217; 1 participant did not supply age on his or her questionnaire and therefore is not included in the total above. SNST = Stroop Neuropsychological Screening Test; PPVT–R = Peabody Picture Vocabulary Test—Revised.

particularly strong for smoking behavior. Importantly, IQ did not account for a significant increment in predicated variance in health behavior over and above SNST performance after controlling for education and demographic variables for number of pack years smoked ($\beta = .007$; R^2 change = .000, $p = .935$), drinking behavior ($\beta = .083$; R^2 change = .004, $p = .388$), or sleep difficulties ($\beta = .136$; R^2 change = .012, $p = .177$). Thus, we found evidence that executive function is a stronger predictor of health behavior tendencies than general cognitive ability; indeed, although executive function predicts health behavior tendencies over and above IQ, the reverse is not true. Finally, neither IQ nor SNST scores were reliable predictors of exercise behavior ($\beta = .096$; R^2 change = .008, $p = .260$).

Discussion

The temporal contingency structure of health behaviors makes their performance highly sensitive to individual differences in capacity to effortfully regulate behavior. It has been empirically demonstrated that health risk behaviors are perceived to be front end loaded with benefits, whereas health protective behaviors are perceived to be front end loaded with costs (Hall & Fong, 2005). For this reason, it was expected that individual differences in dispositional self-regulatory capacity would predict health behavior tendencies in the general population. The present findings provide some tentative support for the contention that one facet of self-regulatory capacity—biologically imbued executive function—is associated with health risk and health maintaining behaviors.

Of special significance is the finding that after controlling for demographics and education, IQ was no longer predictive of smoking behavior, substance use, or sleep habits; however, for all three of these health behaviors, a measure of executive function provided a significant increment in prediction over and above education, demographics, and overall IQ. This provides some initial support for the notion that health behaviors may not be driven by general cognitive function or educational attainment but rather by executive function specifically. This is very consistent with conceptualizations of prefrontal cortex function and its role in behavioral self-regulation (Fuster, 1997; Koechlin, Ody, & Kouneiher, 2003) and may challenge assumptions that IQ-mortality associations are mediated by IQ-driven deficits in complex problem-solving ability (Gottfredson, 2004).

Recently, Deary and Der (2005) have argued for reduction of the IQ construct to simple reaction time, citing data suggesting that the IQ-mortality association was even stronger for a simple measure of reaction time than for overall IQ as measured by standardized testing. We suggest that performance on Deary's reaction time measure may in fact be a close proxy for executive function. There is less theoretical justification to support the notion that reaction time as a construct should be associated with either health behavior or mortality as an end point. However, there is a wealth of

Table 3
Predictors of Smoking Behavior

Variable	β	$F(1, 136)$	Change R^2	Significance of R^2 change
Step 1		5.249	.102	.002
Age (years)	.163			
Gender	.284			
Education	−.056			
Step 2		0.486	.003	.487
PPVT–R	−.069			
Step 3		65.480	.291	.000
SNST performance (errors)	.564			

Note. Dependent: number of pack years smoked; $R^2 = .396$. PPVT–R = Peabody Picture Vocabulary Test—Revised; SNST = Stroop Neuropsychological Screening Test.

Table 4
Predictors of Alcohol Consumption (Problems With Alcohol)

Variable	β	$F(1, 142)$	Change R^2	Significance of R^2 change
Step 1		10.325	.177	.000
Age (years)	.301			
Gender	−.232			
Education	.070			
Step 2		0.623	.004	.431
PPVT–R	.075			
Step 3		3.932	.022	.049
SNST performance (errors)	.155			

Note. Dependent: problems with alcohol; $R^2 = .203$. PPVT–R = Peabody Picture Vocabulary Test—Revised; SNST = Stroop Neuropsychological Screening Test.

Table 5
Predictors of Sleep Difficulties

Variable	β	$F(1, 144)$	Change R^2	Significance of R^2 change
Step 1		0.982	.020	.403
Age (years)	−.103			
Gender	−.095			
Education	.034			
Step 2		1.469	.010	.227
PPVT–R	.123			
Step 3		7.249	.047	.008
SNST performance (errors)	.224			

Note. Dependent: difficulties with sleep; $R^2 = .076$. PPVT–R = Peabody Picture Vocabulary Test—Revised; SNST = Stroop Neuropsychological Screening Test.

experimental and observational evidence to suggest that executive function should be associated with effortful behavioral self-regulation, of the sort required for consistent performance of health protective behaviors and avoidance of health risk behaviors over time (Fuster, 1997; Hall & Fong, 2005).

Limitations

Limitations to the present study must be considered. One significant limitation is the cross-sectional design used. Because both cognitive function and health behavior were measured during the same testing session, it is not possible to disentangle direction of causality. Indeed, there is evidence to suggest that, for example, significant alcohol consumption is causally associated with impaired frontal lobe function (Moselhy, Georgiou, & Kahn, 2001). Thus, the case could reasonably be made that the observed associations between drinking behavior and cognitive function are in the opposite direction from what was hypothesized. Only a prospective and/or experimental design would allow definitive statements to be made about causality. The case is less clear, however, for smoking behavior and sleeping behavior. Regardless, the possibility of bidirectional influence should be considered carefully. Also limiting this study was reliance on a single-item measure of exercise, which could have contributed to the null finding through unreliability of measurement. Similarly, reliance on the single-item measure of sleep may have led to an underestimation of its true association with the predictor variable; subsequent studies should include standardized, multi-item assessment of these behaviors. Finally, it is possible that specific facets of executive function may be differentially predictive of health protective versus health risk behaviors, given that avoiding the latter necessitates acts of omission (e.g., resisting the urge to light up a cigarette), whereas performing the former necessitates acts of commission (e.g., consistently attending a fitness class). Future research should examine these possibilities.

Limitations notwithstanding, the present study contributes to the existing literature on cognitive function and health by proposing evidence for the association between executive function and health behavior. As such, we suggest that health behavior may indeed be a mediating variable for the IQ-mortality associations described earlier. Importantly, these findings provide support for one of the central tenets of the Temporal Contingency Theory (Hall & Fong, 2005): Self-regulatory capacity is associated with health behavior tendencies. An interesting direction for future research would be to explicitly investigate the association between state fluctuations in executive function and health behavior performance. Functional imaging studies that examine regional activation and self-regulatory tendencies in the domain of health would also be potentially informative.

Implications for Individual- and Policy-Level Intervention

Some may question the practical importance of understanding biologically imbued or brain-based limitations on capacity for behavioral self-regulation, particularly for individual-level intervention. In fact, such understanding is crucially important. For example, if biologically imbued self-regulatory limitations exist, individuals may well be advised to undertake behavior change in one domain at a time and to expect lapses at times when regulatory resources are disrupted (e.g., when ingesting substances that hamper prefrontal cortex function, such as alcohol, or following physical insult to the prefrontal areas). Conversely, behavioral or pharmacologic interventions that enhance executive function should stand to enhance capacity to regulate behavior along more healthy trajectories (e.g., Colcombe et al., 2004).

There are also important public health implications for understanding self-regulatory limits and potentials. Behavioral contingencies are partially supplied by the environmental context in which the behavior occurs, and so the problem does not lie solely within the behavior itself; it also lies within the context in which the behavior occurs. For example, the increasing urbanization of the Western living environment has made incidental physical activity difficult and unhealthy food choice easy. Essentially, our environment has manufactured an unfavorable temporal contingency profile for health protective behaviors. The good news is that environments can be restructured so as to reduce such unfavorable immediate contingencies; this is essentially the rationale for the ecological approach to health promotion (Sallis & Owen, 2002). Engineering environments to facilitate health protective behaviors and discourage health risk behaviors remain an exciting avenue for future research (see Frank, Andersen, & Schmid, 2004; Moskowitz, Lin, & Hudes, 2000).[4] Theorizing along these lines should be guided by the notion that the ultimate objective of ecological intervention is to reduce self-regulatory demands of health protective behaviors and to make health risk behaviors more taxing on self-regulatory resources.

[4] Environmental smoking bans are a prime example of this latter approach. Public policymakers and municipalities around the world have succeeded in manufacturing environments in which lighting up a cigarette has become associated with a dramatically different temporal contingency structure than it was in the past. The immediate contingencies associated with lighting up a cigarette in areas with environmental smoking bans now include inconvenience, time cost, and social disapproval. This is a significant change from decades ago when lighting up a cigarette at one's desk was associated with no significant time cost or inconvenience and may have actually been accompanied by social approval.

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