Executive Functioning as a Mediator of the Relationship Between Premorbid Verbal Intelligence and Health Risk Behaviors in a Rural-Dwelling Cohort: A Project FRONTIER Study

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Abstract

Limited research is available regarding the impact of neuropsychological functioning on health risk behaviors in rural-dwelling elderly populations. This cross-sectional study examined the relationships between estimated premorbid verbal IQ (AMNART), executive functioning impairment (EXIT25), and health risk behaviors including alcohol use (AUDIT), smoking, compliance with recommended cancer screenings, and obesity (BMI). The total sample included 456 English-speaking adults and older adults of non-Hispanic White and Hispanic origin seen as part of an ongoing study of rural cognitive aging, Project FRONTIER. Regression analyses revealed significant independent effects of AMNART and EXIT25 on most health risk behaviors, and supported the hypothesized mediating role of EXIT25 on the relationships between AMNART and smoking, cancer screenings, and BMI in both cognitively impaired and healthy subgroups. This study clarifies the relationships between executive functioning, premorbid IQ, and health risk behaviors in diverse groups, and confirms that premorbid IQ represents an important determinant of health behaviors and neurocognitive outcomes.

Keywords: Executive functioning; Diversity; Cognition; Health risk behaviors; Premorbid verbal IQ; geriatrics

Over the past several decades, increased scientific interest has been directed at health risk behaviors, in part due to the realization that such behaviors represent important determinants of preventable diseases and premature mortality (McGinnis & Foege, 1993). Health risk factors such as smoking and obesity have been evaluated in relation to a variety of morbidities including dementia (Fratiglione, Ahlbom, Vitanem, & Winblad, 1993; Graves et al., 1990; Hirdes & Forbes, 1992; Patterson, Haines, & Pokin, 1994; Sabia, Kivimaki, Shipley, Marmot, & Singh-Manoux, 2009; Wiley & Camacho, 1980; Wilson, 1994), and health-protective behaviors such as physical fitness and healthy diet choices have been shown to confer some protection against neurocognitive decline (e.g., Hahn & Andel, 2011; McAuley, Kramer, & Colcombe, 2004). This line of research provides evidence for the significant influence of certain health risk behaviors on neurocognitive functioning. Although these early studies specified a unidirectional path from health risk behaviors to neurocognitive functioning, more recent investigations examined the inverse of this relationship and demonstrated a significant influence of neurocognitive functioning on health risk behaviors (Cernin, 2008; Hall, Elias, & Crossley, 2006). This underscores the need for efforts to further investigate the nature and strength of the association between neurocognitive functioning and health behavior outcomes.

One particular area of neurocognitive functioning that has been shown to have an influence on health behaviors is executive functioning, the cognitive function responsible for integrating isolated and basic mental activities into unified, complex, and goal-directed cognitive activities (Royall et al., 2003). Executive functioning has been argued to play a role in health risk behaviors as it allows for the planning, execution, and regulation of these behaviors. Consistent with this argument, a number of studies have demonstrated that executive functioning (as assessed through tasks of selective attention and cognitive flexibility,
including the Stroop test and the Go/No-Go Task) is a significant predictor of health risk behaviors including smoking status, alcohol consumption, physical activity, diet choices, and physical fitness (Hall et al., 2006; Hall, Fong, Epp, & Elias, 2008). In addition, deficits in executive functioning have been linked to poorer adherence to medical regimens (e.g., treatment adherence; Solomon & Halkitis, 2008) and have to show influence the relationship between behavioral intention and performance of various health risk behaviors (Hall et al., 2006).

However, the interpretation of these findings is complicated by the fact that sociodemographic factors concurrently influence health risk behaviors (Adler, Boyce, Chesney, Folkman, & Syme, 1993; Elo & Preston, 1996; Marmot, Kogeivas, & Elston, 1987; Pappas, Queen, Hadden, Fisher, 1993). Specifically, past studies have shown associations between various sociodemographic factors (e.g., age, low socioeconomic status) and health risk behaviors, including the tendency to lead a sedentary life-style, obesity, smoking, and health-screening practices (Deeks, Lombard, Michielmore, & Teede, 2009; Wagenknecht et al., 1990; Winkley, Fortman, & Barrett, 1990). Of particular relevance to investigating the associations between executive functioning and health risk behaviors is the consideration of educational attainment. Past research examining the relationships between education and health risk behaviors has found mixed results, with a number of findings supporting a negative association between education and smoking, excessive alcohol consumption, obesity, and lack of physical exercise (e.g., Brunello, Fort, Schneeweis, & Winter-Ebmer, 2011; Schnohr et al., 2004), and others failing to find any significant effects (Braakmann, 2011; Clark and Royer, 2010; Oreopolous, 2007). In part, this discrepancy in findings has been attributed to the possible confounding effect of education on executive functioning.

Furthermore, although past research consistently demonstrated strong associations between educational attainment and health risk behaviors, the interpretation of these findings is limited because years of education is typically used as the primary operationalization of education. However, there is substantial evidence that schooling characteristics may vary across socioeconomic contexts, meaning that equivalent years of education across contexts may not equate to similar knowledge nor similar influence on executive functioning and other variables (Gurland et al., 1992; Manly et al., 2002). Consequently, premorbid verbal intelligence has been offered as a more precise measure of educational attainment as it is widely agreed to be an index of quality of education (Manly, Jacobs, Touradji, Small, & Stern, 2002).

Past research has provided evidence of a link between education and performance on tasks of executive functioning including the Stroop test (Bakos et al., 2008), Semantic Fluency test, Modified Card Sorting test (Plumet, Gil, & Gaonac’h, 2005), and the Trail Making Test, Part B (Johnson, Ficker, & Lichtenberg, 2006; Tombaugh, 2004; Voos, Custódio, & Malaquias, 2011). In particular, Cernin (2008) reported significant associations between educational attainment and health risk behaviors including sleep, diet, and exercise, and between executive functioning (as indexed by the Trail Making Test, Category Fluency Test, and the Controlled Oral Word Association Test) and health risk behaviors in a sample of cognitively healthy African-American older adults. Importantly, the author demonstrated that the influence of educational attainment on health behaviors occurs through its effect on executive functioning. While progress has been made in describing and explaining the relationships between education, health risk behaviors, and executive functioning, much remains to be elucidated regarding the specific mechanisms involved in different sociodemographic subgroups.

Previous research has found independent associations between executive functioning and health risk behaviors and between education and health risk behaviors (e.g., Hall et al., 2006; Schnohr et al., 2004); however, only Cernin (2008) has included both executive functioning and education in a model linking both of these variables to health risk behaviors, and this study only looked at cardiovascular risk factors including sleep, diet, and exercise in a cognitively intact sample. In addition, efforts are needed to further investigate the link between quality of education as indexed by premorbid verbal IQ, executive functioning, and health risk behaviors. This study sought to address many of these limitations in the extant literature. Therefore, the aims of the current study are as follows: (i) to further investigate the relationships between estimated premorbid verbal IQ, executive functioning, and health risk behaviors, including alcohol consumption, smoking, obesity, and compliance with recommended cancer screenings; and (ii) to test a mediating effect of executive functioning in the relationships between estimated premorbid verbal IQ and health risk factors in a sample of English-speaking Hispanic and non-Hispanic White older adults. The following hypotheses will be tested: (i) both estimated premorbid IQ and executive functioning will be independently and negatively related to smoking, alcohol use, and obesity, and positively associated with compliance with recommended cancer screenings when tested in separate models; and (ii) the relationships between estimated premorbid IQ and health risk behaviors will be fully mediated by executive functioning. Because previous studies varied in the extent to which they relied on cognitively healthy versus impaired samples, these hypotheses were first tested based on the complete community-dwelling sample composed of cognitively impaired and cognitively intact participants, and then repeated in the cognitively healthy subgroup, excluding all participants with cognitive dysfunction. This procedural step was implemented to facilitate generalization and comparison with previous research.
Methods

Procedures

Data were analyzed from a sample of 456 English-speaking, non-Hispanic White and Hispanic participants recruited as part of Project FRONTIER, an ongoing epidemiological study of health among rural-dwelling individuals that began in 2008. Project FRONTIER researchers have spent several years establishing and maintaining community ties through local advisory boards, presentations, hiring of local workers into the research infrastructure, and partnering with community entities for completion of parts of the research protocol (i.e., blood work and medical examinations).

The protocol includes a standardized medical examination, clinical labs, neurocognitive testing, and an interview with participants and an informant. Inclusion criteria are (i) age 40 and above and (ii) residing in one of the counties participating in Project FRONTIER. The two counties included in Project FRONTIER at the time of data collection were Cochran County and Parmer County, both located on the Texas–New Mexico border, though additional sites have been added since the completion of data collection for these analyses. Participant recruitment is conducted by community recruiters through brochures/flyers, presentations, and events, as well as in-person and/or door-to-door solicitation, the latter of which is by far the most successful means of participant recruitment. These recruitment procedures are discussed in more detail elsewhere (O’Bryant, Schrimsher, Johnson, & Zhang, 2011). Project FRONTIER is conducted under an Institutional Review Board-approved protocol and all participants signed written informed consent.

The analyses were first conducted with the total sample including both cognitively impaired and cognitively healthy participants, and then repeated with the subgroup of cognitively healthy participants. Those who exhibited cognitive dysfunction were excluded from the cognitively healthy subgroup, and cognitive impairment was determined by consensus of a panel composed of a clinical neuropsychologist and medical doctors who reviewed available data from neurocognitive tests and clinical interviews. Data gathered from these two sources were utilized as indicators of any previous diagnosis, cognitive difficulties, and functional impairments (e.g., difficulty performing activities of daily living such as driving). The consensus diagnosis procedures were more thoroughly described elsewhere (O’Bryant, Schrimsher, Johnson, & Zhang, 2011). Participants were excluded from the study if they exhibited testing impairment or questionable effort during testing, and if they reported a history of comorbid medical or psychiatric issues susceptible of influencing neurocognitive functioning, such as strokes, transient ischemic attacks, head injury, and Parkinson’s disease.

Measures

The Executive Interview, 25 Items (EXIT25; Royall, Mahurin, & Gray, 1992). The EXIT25 is a measure of executive functioning that consists of 25 items including an interference task, a go/no-go task, design fluency, memory, and motor sequencing. The EXIT25 gives total scores ranging from 0 to 50, with higher scores suggesting greater deficits of executive functioning. A cut-score of 15 out of 50 is typically used to discriminate non-demented control subjects from both cortically and non-cortically demented subjects in elderly populations. The subtasks are administered in relatively rapid succession and participants are provided with limited instructions, which require participants to quickly inhibit incorrect responses. The EXIT25 is highly correlated with other measures of executive functioning, including the Wisconsin Card Sorting Task, Trail Making Test Part B, Lezak’s Tinker Toy Test, and the Test of Sustained Attention (Royall et al., 1992; Royall, Palmer, Chiodo, & Polk, 2005). The EXIT25 has been found to have high internal validity ($\alpha = 0.85$) and high interrater reliability ($r = .91$) (Stockholm, Vogel, Gade, Waldemar, 2005). This test has also been shown to be more sensitive than the MMSE at identifying the presence of milder levels of cognitive impairments (Stockholm et al., 2005).

The American Version of the National Adult Reading Test (AMNART; Grober & Sliwinski, 1991). The AMNART was utilized to measure estimated premorbid verbal IQ, and it is commonly utilized as an index of quality of education (Cosentino, Manly, & Mungas, 2007; Manly, Jacobs, Touradji, Small, & Stern, 2002). Scores on this measure represent the total number of errors evidenced by participants on a task requiring them to pronounce 45 words of varying difficulty written on a sheet of paper. The estimated premorbid IQ was derived from the AMNART using Grober and Sliwinski’s (1991) formula that includes number of errors made and years of education, with a mean IQ of 100 and standard deviation of 15. This score was used as an index of premorbid verbal IQ in the current study and a proxy measure for quality of education, as has been commonly done in past research (Cosentino, Manly, & Mungas, 2007). This measure has been shown to be a valid instrument with adequate construct validity and convergent validity (Crawford, Deary, Starr, & Whalley, 2001; Lastine-Sobecks, Jackson, & Paolo 1998), and good internal reliability (Spreen & Strauss, 1998).
The Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 1993). The AUDIT was used to identify unhealthy alcohol use patterns that may place participants at risk for alcohol use disorders. This 10-item measure includes questions assessing the amount and frequency of alcohol intake (items 1–3), alcohol dependence (items 4–6), and problems related to alcohol consumption (items 7–10). Scores can range from 0 to 40, with higher scores indicating increased risk for alcohol use problems; a cut-off point of 8 is typically used to delineate potentially hazardous alcohol intake from more normal patterns of alcohol use (Reinnert & Allen, 2007; Saunders et al., 1993). The total score from this measure was used in all analyses. The validity and reliability of this test have received ample support in past research (Lima et al., 2005), and the AUDIT has been shown to have adequate sensitivity, specificity (Reinnert & Allen, 2007), and internal validity above 0.80 (Babor, Higgins Biddle, Saunders, & Monteiro, 2001; Moussas et al., 2009).

Other Measures. Health risk behavior assessments included body mass index (BMI), smoking status (i.e., currently smokes tobacco or does not currently smoke tobacco), and number of cancer screenings. BMI was calculated from participants’ weight (in pounds) and height (in inches) to estimate body fat obtained as part of the medical examinations. Standard BMI calculations (for pounds and inches) consist of dividing weight by squared height and multiplying this product by a conversion factor of 703 (weight (lb)/height (in).^2 × 703) (Gadzik, 2006), with higher scores indicating higher body fat and possible weight-related health problems, such as obesity (Note that the formula for kilograms and meters (weight (kg)/[height (m)].^2) provides the same results). A self-report questionnaire was administered to collect information regarding smoking behavior and past cancer screenings. Participants were asked to answer two questions inquiring whether they smoked tobacco in the past, and whether they were current tobacco smokers. Answers from these two questions were combined into a dichotomous variable designating smoking status (yes/no), and entered as such in subsequent analyses. A global measure of cancer screening behaviors was utilized as a proxy for whether they had complied with recommendations to seek any of the following cancer screenings: Blood Stool Test, Sigmoidoscopy/Colonoscopy, Mammogram, Clinical Breast Exam/Pap Test, or Prostate-specific Antigen Test. A gender-specific average score based on the total number of cancer screenings was computed based on the frequency of cancer screenings aggregated across screening types, and this score was used in all subsequent analyses. As described in the following section, differences in basic sociodemographic characteristics were controlled for in the process of examining the relationships between the key predictor variables and health behaviors.

Statistical Analyses

Regression analyses were conducted to examine the effects of EXIT25 and AMNART on each health risk behavior in separate models. Prior to performing the regression analyses, data were evaluated according to the assumptions of linear regression (linearity, homoscedasticity, normality of errors, and the absence of multicollinearity). The test assumptions were met for all variables except AUDIT scores, and multicollinearity between AMNART and EXIT25 was not problematic. The regression models were either linear or logistic depending on the criterion variable used, with linear regressions being used for all analyses except those including the AUDIT as the dependent variable. AUDIT scores were significantly positively skewed and evidenced leptokurtosis, indicating non-normal distribution. Consequently, negative binomial regression analyses were conducted to correct for this non-normality as well as over dispersion (Cox, West, & Aiken, 2009). In addition, logistic regression analyses were utilized to examine the variance accounted for by EXIT25 and AMNART in smoking status, which was entered as a dichotomous criterion variable. Pearson’s bivariate correlations were used to examine the relationships between key sociodemographic variables, predictors, and dependent variables. Sociodemographic variables were included as covariates in all subsequent regression analyses if they were significantly correlated with the dependent variables.

Mediation analyses were then conducted based on Baron and Kenny’s (1986) guidelines using several regression analyses to examine changes in the predictive value of AMNART (X) in health risk behaviors (Y) upon entering EXIT25 (mediator; M) in the model. Full mediation is assumed when the path from X to Y becomes nonsignificant after controlling for M, and partial mediation can be inferred if the significance of the path from X to Y is decreased upon entering M in the model. Sobel tests were then conducted by calculating the indirect effect pathway by multiplying the two regression coefficients (i.e., direct M to Y pathway as well as the indirect pathway between X to Y) based on standard guidelines (Sobel, 1982) to assess for the significance of the mediated effect.

The analyses were first conducted with the complete sample composed of both cognitively impaired and healthy participants. The analyses were then repeated with the cognitively healthy subgroup, with participants exhibiting dementia or mild cognitive impairment excluded based on the consensus diagnosis criteria described previously.
Results

Table 1 presents the demographic characteristics and correlations among key variables. In the total sample of 456 individuals, the mean age of participants was 62.37 years (SD = 12.70, range = 40–96), with a mean of 12.44 years of education. A total of 317 participants were women (69.5%). The total sample was composed of 362 cognitively healthy individuals (80%); 91 participants received a consensus diagnosis of cognitive dysfunction (20%), with 81 diagnosed with mild cognitive impairment (17.8%) and 10 with dementia (2.2%). Among non-smokers, the mean age and education was 64.28 (SD = 12.82) and 12.77 years (SD = 3.07), respectively, compared with 60.51 (SD = 12.32) and 12.11 years (SD = 2.92) among smokers. The majority of non-smokers were women (n = 188, 83.5%), and 56% (n = 129) of smokers were women.

The first set of analyses tested the hypothesis that estimated premorbid IQ and executive functioning would each account for significant portions of the variance in health risk behaviors in separate models. Linear regressions were used for all analyses except those including the AUDIT as the dependent variable. Results for all regression analyses are presented in Tables 2 and 3. AMNART had a significant effect on BMI scores (b = −0.061 (0.028), t = −2.143, p = .033) and accounted for 4.8% of the total variance in BMI in the final regression model, F(3,449) = 7.477, p < .001. Sociodemographic factors including age and gender were entered as a first step and accounted for 3.8% of the variance in BMI, F(2,449) = 8.848, p < .001. In a second regression analysis, AMNART had a significant effect on the number of cancer screenings (b = 0.004 (0.001), t = 3.979, p < .001) after holding age and gender constant. These sociodemographic factors accounted for a total of 15% of the variance in cancer screenings, F(2,448) = 39.539, p < .001, and the final model accounted for 17.9% of the total variance, F(3,447) = 32.508, p < .001. The third regression model indicated that AMNART accounted for a significant 15% of the total variance in smoking status (Nagelkerke’s R² = .15; b = 0.017 (0.007), Wald χ² = 5.573, p = .018) after controlling for age, gender, and years of education. As depicted in Table 3, results from the negative binomial regression analyses indicated that AMNART scores did not account for a significant proportion of variance in AUDIT total scores (b = 0.001 (0.007), Wald χ² = 0.040, p = .842). Because the multiplicative power of this beta weight is so close to 1.0 after accounting for the natural log link used in negative binomial regression (i.e., 1.001), estimated premorbid IQ did not increase our ability to predict AUDIT total scores beyond age, gender, and years of education. Overall, these results indicate that higher estimated premorbid IQ is associated with decreased health risk behaviors, including lower BMI, more cancer screenings, and lower rates of smoking, while failing to increase alcohol use.

Table 1. Descriptive statistics and correlations

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7 (Men)</th>
<th>7 (Women)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD) complete sample</td>
<td>62.40 (12.7)</td>
<td>12.44 (3.1)</td>
<td>107.97 (10.3)</td>
<td>6.74 (4.5)</td>
<td>1.16 (2.9)</td>
<td>29.36 (6.3)</td>
<td>0.55 (0.3)</td>
<td>0.59 (0.2)</td>
</tr>
<tr>
<td>Mean (SD) Cognitive healthy sample</td>
<td>60.93 (12.3)</td>
<td>12.71 (3.0)</td>
<td>109.53 (9.7)</td>
<td>5.59 (3.5)</td>
<td>1.20 (2.9)</td>
<td>29.57 (6.3)</td>
<td>0.60 (0.3)</td>
<td>0.59 (0.2)</td>
</tr>
<tr>
<td>Mean (SD) Cognitively Impaired sample</td>
<td>68.15 (12.8)</td>
<td>11.33 (2.5)</td>
<td>101.50 (10.2)</td>
<td>11.43 (5.1)</td>
<td>1.01 (2.9)</td>
<td>28.53 (6.3)</td>
<td>0.54 (0.3)</td>
<td>0.60 (0.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measure</th>
<th>Non-Hispanic</th>
<th>Hispanic</th>
<th>Female</th>
<th>Smoking-Yes</th>
<th>MCI</th>
<th>Diagnosis</th>
<th>Dementia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number (percentage): complete sample</td>
<td>330 (72.4)</td>
<td>126 (27.6)</td>
<td>317 (69.5)</td>
<td>231 (50.7)</td>
<td>81 (17.8)</td>
<td>10 (2.2)</td>
<td></td>
</tr>
<tr>
<td>Number (Percentage): Cognitive healthy subgroup</td>
<td>265 (73.2)</td>
<td>97 (26.8)</td>
<td>255 (70.44)</td>
<td>179 (49.4)</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Number (Percentage): Cognitively impaired subgroup</td>
<td>65 (69.14)</td>
<td>29 (30.86)</td>
<td>62 (65.95)</td>
<td>52 (55.31)</td>
<td>81 (86.17)</td>
<td>10 (10.63)</td>
<td></td>
</tr>
</tbody>
</table>

Note: All correlations are based on the complete sample (collapsed across gender and cognitive status). SD = Standard deviation; EXIT25 = Executive Interview 25-item Examination; AMNART = American Version of the National Adult Reading Test; AUDIT = Alcohol Use Disorders Identification Test; BMI = Body Mass Index; MCI = Mild Cognitive Impairment.

*p < .05, two-tailed; **p < .01, two-tailed.
smoking status (Nagelkerke’s variable. A logistic regression analysis provided evidence that EXIT25 scores accounted for a significant 15% of variance in complete model including EXIT25 accounted for a total of 17.6%.

2. Cancer Screenings
Sociodemographic factors accounted for 15.3% \((p = .001)\) of the variance in this criterion after holding age and gender. As depicted in Table 3, results from the negative binomial regression analysis indicated that EXIT25 total scores were significantly and negatively associated with AUDIT total scores after holding gender, age, and years of education constant \((b = -0.050 (0.020); \text{Wald } \chi^2 = 6.025, p = .014)\). This pattern of results indicates that for every one-point increase in EXIT25 scores, AUDIT scores are multiplied by 0.951. The direction of this result indicates that poorer executive functioning is associated with lower alcohol intake though the magnitude of association is small.

### Table 2. Linear regression analyses for reading ability and executive functioning effects on health risk behaviors

<table>
<thead>
<tr>
<th>Variables</th>
<th>Complete sample</th>
<th>Cognitively healthy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
</tr>
<tr>
<td>1. BMI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 1. Predicted by EXIT25</td>
<td>.144</td>
<td>.069</td>
</tr>
<tr>
<td>Model 2. Predicted by AMNART</td>
<td>-.061</td>
<td>.028</td>
</tr>
<tr>
<td>Model 3. EXIT25 Predicted by AMNART</td>
<td>-.138</td>
<td>.024</td>
</tr>
<tr>
<td>Model 4. Relationship Between AMNART and Cancer Screenings as mediated by EXIT25</td>
<td>-.04</td>
<td>.03</td>
</tr>
</tbody>
</table>

Notes: \(B = \) unstandardized regression coefficient; \(SE = \) standard error of unstandardized regression coefficient; \(\beta = \) standardized regression coefficient; \(pr = \) partial correlation coefficient; \(Adj R^2 = \) Adjusted \(R^2\) Squared; EXIT25 = Executive Interview 25-item Examination; AMNART = American Version of the National Adult Reading Test; BMI = Body Mass Index.

*\(p < .05\), two-tailed; **\(p < .01\), two-tailed; ***\(p < .001\), two-tailed.

### Table 3. Logistic and negative binomial regression analyses for reading ability and executive functioning effects on health risk behaviors

<table>
<thead>
<tr>
<th>Variables</th>
<th>Complete sample</th>
<th>Cognitively healthy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
</tr>
<tr>
<td>1. Smoking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 1. Predicted by EXIT25</td>
<td>.066</td>
<td>.025</td>
</tr>
<tr>
<td>Model 2. Predicted by AMNART</td>
<td>.017</td>
<td>.007</td>
</tr>
<tr>
<td>Model 3. EXIT25 Predicted by AMNART</td>
<td>-.138</td>
<td>.024</td>
</tr>
<tr>
<td>Model 4. Relationship Between AMNART and Smoking is fully mediated by Smoking</td>
<td>.014</td>
<td>.007</td>
</tr>
</tbody>
</table>

Notes: EXIT25 = Executive Interview 25-item Examination; AMNART = American Version of the National Adult Reading Test; BMI = Body Mass Index; AUDIT = Alcohol Use Disorders Identification Test.

*\(p < .05\), two-tailed; **\(p < .01\), two-tailed; ***\(p < .001\), two-tailed.

The effects of EXIT25 on health behaviors were also examined in separate models as part of the first hypothesis testing. A significant effect of EXIT25 on BMI scores was noted \((b = 0.144 (0.069), t = 2.093, p = .037)\) after holding age and gender constant. The sociodemographic variables were entered as a first step and accounted for a significant 3.8% of the variance in BMI, \(F(2,451) = 8.831, p < .001\), and the final regression model including EXIT25 explained 4.7% of the total variance in BMI, \(F(4,443) = 5.88, p < .001\). A second regression analysis indicated that EXIT25 was also significantly associated with number of cancer screenings \((b = -0.008 (0.002), t = -3.553, p < .001)\) after controlling for age and gender. Sociodemographic factors accounted for 15.3% \((F(2,453) = 40.772, p < .001)\) of the variance in cancer screenings, and the complete model including EXIT25 accounted for a total of 17.6%, \(F(3,453) = 32.09, p < .001\), of the variance in this criterion variable. A logistic regression analysis provided evidence that EXIT25 scores accounted for a significant 15% of variance in smoking status (Nagelkerke’s \(R^2 = .15; b = 0.066 (0.025); \text{Wald } \chi^2 = 7.005, p = .008\)) after holding age, gender, and education constant. As depicted in Table 3, results from the negative binomial regression analysis indicated that EXIT25 total scores were significantly and negatively associated with AUDIT total scores after holding gender, age, and years of education constant \((b = -0.050 (0.020); \text{Wald } \chi^2 = 6.025, p = .014)\). This pattern of results indicates that for every one-point increase in EXIT25 scores, AUDIT scores are multiplied by 0.951. The direction of this result indicates that poorer executive functioning is associated with lower alcohol intake though the magnitude of association is small.
The second hypothesis was that the relationships between estimated pre-morbid IQ and health risk behaviors would be fully mediated by executive functioning. Based on Baron and Kenny’s (1986) guidelines for determining mediation, we tested the hypothesis that executive functioning would mediate the link between estimated premorbid IQ and health risk behaviors. Results are presented in Tables 2 and 3. A key step in Baron and Kenny’s (1986) guidelines consists of ensuring that the criterion variable and mediating variable are significantly associated using regression analysis. AMNART was significantly correlated with EXIT25, our hypothesized mediator variable \((b = -0.138 (0.024), t = -5.852, p < .001)\) after controlling for relevant sociodemographic variables. Specifically, gender, age, and years of education accounted for a total of 25% of the variance in EXIT25, \(F(3,448) = 50.578, p < .001\), and the final model including AMNART explained 31% of the total variance in this outcome, \(F(4,448) = 49.327, p < .001\). Also, as described previously, AMNART and EXIT25 were both independently and significantly related to BMI, number of cancer screenings, and smoking status. However, only executive functioning was significantly associated with AUDIT scores; thus mediation could not be tested using AUDIT scores as the criterion variable. EXIT25 was found to fully mediate the relationship between AMNART and smoking behavior. Specifically, AMNART total scores were no longer related to smoking behavior \((b = 0.014 (0.007), \text{Wald } \chi^2 = 3.819, p = .051; \text{Sobel’s test} = 2.57, p < .01)\), upon controlling for EXIT25 total scores \((b = 0.063 (0.026), \text{Wald } \chi^2 = 5.974, p = .015)\). In contrast, EXIT25 was found to partially mediate the relationship between AMNART and cancer screenings, as seen in the reduced yet significant effect of AMNART scores \((b = 0.003 (0.001), t = 2.300, p = .022; \text{Sobel’s test} = 3.77, p < .001)\) after controlling for EXIT25 scores \((b = -0.006 (0.003), t = -2.14, p = .033)\), age, and gender. Sociodemographic variables explained 15.9% of the variance in cancer screenings, \(F(2,444) = 42.315, p < .001\), and the final mediation regression model accounted for 19.3% of the total variance in cancer screenings, \(F(4,444) = 26.54, p < .001\). Full mediation was also supported for BMI, as the predictive value of AMNART total scores on BMI became non-significant when EXIT25 total scores were entered in the regression equation after controlling for age and gender \((b = -0.045 (0.078), t = 1.392, p = .165; \text{Sobel’s test} = -2.05, p < .05)\). The effect of EXIT25 on BMI also became nonsignificant in the final model \((b = 0.097 (0.032), t = 1.240, p = .216)\).

An additional set of analyses was conducted to examine whether this pattern of findings would replicate in a subgroup of cognitively healthy participants. After exclusion of all cognitively impaired participants, results were consistent with the pattern of findings described above. This set of results is depicted in Tables 2 and 3.

**Discussion**

This study aimed to examine the relationship between executive functioning, estimated premorbid verbal IQ, and health risk behaviors in an English-speaking sample of Hispanic and non-Hispanic White individuals. The results of this study partially supported our hypotheses that executive functioning would mediate the relationships between estimated premorbid IQ and a variety of health risk behaviors. Full mediation by executive functioning was confirmed for the relationship between estimated premorbid IQ and smoking status, and between estimated premorbid IQ and BMI, indicating that estimated premorbid IQ is strongly associated with these health behaviors through its effect on executive functioning. A surprising finding was that the associations between EXIT25 and BMI and between AMNART and BMI both became non-significant when entered as concurrent predictors in the model. This suggests that EXIT25 and AMNART have sufficient overlap that neither explains any variance in BMI beyond what the other explains. Executive functioning also partially mediated the relationship between estimated premorbid IQ and number of cancer screenings. In addition, mediation was not found for the relationship between estimated premorbid IQ and alcohol use. This may be due to the fact that there was relatively little variability in AUDIT scores, which reduced the effects of estimated premorbid IQ and executive functioning. In addition, our sample included older adults, and previous research has indicated that the AUDIT does not perform especially well among this population (Aalto, Alho, Halme, & Seppa, 2011). However, overall it appears that both estimated premorbid IQ and executive functioning are strongly related to a number of health risk behaviors, and that executive functioning acts as a mediator of the relationships between estimated premorbid verbal IQ and certain health risk behaviors.

Our findings replicate and expand on the current literature in a number of ways. Consistent with Kisses and Alexopoulos (2005), we found that executive functioning is strongly associated with engagement in health risk behaviors. In addition, our findings reiterated the previously reported importance of educational attainment to health risk behaviors (e.g., Winkleby et al., 1990) and links between estimated premorbid IQ and executive functioning (e.g., Tombaugh, 2004). To date, this is the only study that has examined executive functioning as a mediator of the relationships between estimated premorbid verbal IQ and health risk behaviors in an English-speaking sample of non-Hispanic Whites and Hispanics, and that tested the integrity of these findings across subgroups of cognitively intact and impaired adults and older adults. In doing so, we provide the first evidence for a model including all three of these variables. The results of our follow-up analyses excluding cognitively impaired participants indicated that our main findings remained when only cognitively healthy adults and older adults were...
included. This is consistent with previous studies relying on cognitively intact samples (e.g., Cernin, 2008) and suggests that the relevance of our findings generalizes to both cognitively impaired and healthy subgroups.

This study is also one of the first to examine the effects of estimated premorbid verbal IQ on health risk behaviors, as opposed to solely relying on years of education. Premorbid verbal intelligence has been shown to be a valid and reliable index of quality of education (Cosentino, Manly, & Mungas, 2007; Manly, Jacobs, Touradji, Small, & Stern, 2002), and our findings indicate that quality of education is significantly related to certain health behavior outcomes including obesity, compliance with recommended cancer screenings, and smoking. This suggests that quality of education should be considered in examining the influence of educational attainment on neurocognitive functioning and health risk behaviors, as the latter appears to influence these factors. However, more research is needed to examine how this pattern may differ across various health-related outcomes and differing types and severities of neurocognitive dysfunction.

This line of research also has clinical implications. Adherence to provider recommendations is important for positive patient outcomes, making it an essential area for physicians and mental health practitioners to recognize and attempt to improve. While estimated premorbid IQ and executive functioning are generally not readily modifiable, healthcare providers can make adjustments to improve treatment adherence based on these variables (e.g., by reducing the number of recommendations or changing the type and amount of follow-up they conduct for certain health behaviors). The results of this study revealed important differences in the strengths of the associations between estimated premorbid IQ, executive functioning, and health behavior outcomes, with executive functioning being a stronger mediator for BMI and smoking compared with compliance with recommended cancer screenings. One possible interpretation of these findings is that certain health behaviors such as weight control and exerting effort to reduce or to quit smoking may be more complex to execute than other behaviors, including compliance with recommended cancer screenings. As a result, these more complex health behaviors may require greater involvement of executive functions compared with simpler behaviors. Importantly, these results highlight the importance of considering the complex interplay of these variables when developing and deciding upon the most beneficial intervention approaches for different patients. Our global measure of cancer screening behaviors may have also reduced the range in scores and simplified the construct artificially. Given the recent debates in the literature and popular media regarding these very cancer screenings and their guidelines, additional work in this area is certainly warranted as our findings suggest that neuropsychological functioning along with quality of education play important roles when making these recommendations (patient and policy level).

While this study expands upon the current literature and has clinical implications, a number of limitations should be noted. First, the cross-sectional design of the study precludes causal conclusions from being drawn. Future research should utilize a longitudinal design to ensure that poorer premorbid verbal intelligence precedes executive dysfunction and subsequent changes in health risk behaviors. In addition, there has been some disagreement about what the AMNART measures, with previous authors using it to measure reading ability (Manly et al., 2002) and brain reserve capacity (Fein & McGillivray, 2007). Previous research has used the AMNART as a measure of premorbid verbal intelligence (Grober et al., 2008) providing a basis for this use, yet replication of these findings using another measure of verbal intelligence would be valuable to this line of research. Another limitation concerns the restricted range of AUDIT values observed in this study. Specifically, the fact that the majority of AUDIT values centered around zero and fell below standard diagnostic cutoffs precludes us from drawing any inferences as to the nature and direction of the association between executive functioning and actual alcohol use problems. Thus future research should seek to replicate these findings in larger samples presenting with a wider range of alcohol use patterns and risks. Furthermore, the mediation results should be interpreted with caution given possible method effects. In particular, the fact that health behaviors were measured through self-report and that the tests were not specifically created for use in a Hispanic subgroup makes it possible that measurement biases were introduced. Nonetheless, the fact that the mediation analyses were based on a reliable mediating factor with adequate power and that test assumptions were met should have attenuated this problem.

Another methodological question that would be important to examine in future research concerns the role of other sociodemographic variables in moderating these results. For instance, socioeconomic status has been found to significantly predict access to, beliefs about, and perceptions of healthcare (Whitaker et al., 2011), and as such it is possible that it would influence health behaviors including compliance with recommended cancer screenings. The results of this study highlighted this issue in that few of the bivariate correlations between the key predictors and health behaviors were significant, yet these relationships were significant based on the regression analyses. This discrepancy likely resulted from the strong associations between key predictors and sociodemographic variables, which could not be addressed as part of the correlational analyses but were controlled for in the regression analyses. An examination of the partial correlations obtained as part of the regression output supported this notion, with the partial correlations between the key predictors and health behaviors being significant after holding sociodemographic factors constant. This sheds light on the complex etiological bases of health behavior outcomes, and serves as a reminder of the importance of jointly considering these factors when seeking to predict various health behavior outcomes.
Furthermore, although our findings are based on a rural-dwelling sample, the fact that all of our participants are rural-dwellers in West Texas may represent a threat to external validity. As such, replicating these findings in more diverse samples of various ethnic backgrounds and geographic areas would be beneficial. Similarly, the fact that our sample size for English-speaking Hispanics was relatively small and that no cross-ethnic comparisons were established underscores the need for future studies to attempt to replicate these findings with a larger sample size. Also, replication studies are needed with other linguistic groups, as the current cohort was limited to English-speakers. In particular, the known protective impact of bilingualism on executive functioning (Bialystok, Craik, Green, & Gollan, 2010) may attenuate the relationships of interest, as bilingualism may elevate the threshold at which executive impairment can be detected and identified as a significant determinant of various health outcomes.

In spite of these limitations, this study is to our knowledge the first to clarify the role that executive functioning may play in the relationships between estimated premorbid verbal IQ and certain health risk behaviors in English-speaking individuals of non-Hispanic White and Hispanic origin. Body mass index, smoking behaviors, compliance with recommended cancer screenings, and alcohol use are each related to executive functioning. Future research should begin to examine how healthcare providers can use information about estimated premorbid verbal IQ and executive functioning to impact patient adherence to provider recommendations in terms of certain health risk behaviors. If research can build evidence regarding ways to increase such adherence, protocols can be developed and widely implemented to improve patients’ health.

Authors’ Contributions

All authors meet the criteria for authorship and contributed to the development of this work, including conception, data collection and analyses, as well as manuscript preparation.

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Conflict of Interest

None declared.

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