

## Associations between learning principles of cognitive remediation and cognitive and vocational outcomes in early psychosis: An exploratory analysis of RCT data

Authors	Van duin,Daniëlle; Winter,Lars de; Kroon,Hans; Veling,Wim et al
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## Association between personality and cognitive performance in middle-aged and older adults with human immunodeficiency virus (HIV)

Pariya L. Fazeli<sup>a</sup> , John D. Cheatwood<sup>a</sup> , Cierra Hopkins<sup>a</sup>, David E. Vance<sup>a</sup> , Maria R. Shirey<sup>a</sup>, Andres Azuero<sup>a</sup>, and Michael Crowe<sup>b</sup>

<sup>a</sup>School of Nursing, University of Alabama at Birmingham, Birmingham, AL, USA; <sup>b</sup>Department of Psychology, University of Alabama at Birmingham, Birmingham, AL, USA

### ABSTRACT

**Background:** Nearly half of adults with human immunodeficiency virus (HIV) experience HIV-Associated Neurocognitive Disorder (HAND), characterized by cognitive impairments in two or more cognitive domains, which can interfere with everyday functioning. Many factors are thought to influence such cognitive impairments in adults with HIV; one factor seldom examined is personality.

**Objective:** This study investigated the association between five major dimensions of personality (openness, conscientiousness, extraversion, agreeableness, and neuroticism) and cognitive function in older adults with HIV.

**Methods:** In this cross-sectional study, a secondary data analysis was conducted on 261 HIV+ participants. Participants completed a norm-based cognitive battery covering seven cognitive domains, which yielded the following indices: global cognitive impairment, and global and domain-specific T-scores. The Big Five Inventory was used to assess personality traits.

**Results:** Higher openness, conscientiousness, and agreeableness were associated with better performance on individual cognitive domains while agreeableness and openness were also positively associated with global cognitive T-scores ( $p < .01$ ). Only openness significantly predicted global cognition when adjusting for covariates ( $p < .01$ ).

**Discussion:** Openness was associated with better global cognitive function in persons with HIV. This study provides a basis for further investigation of potential mechanisms for the association between personality and cognition in people with HIV in order to ultimately inform intervention strategies.

### KEYWORDS

Agreeableness; conscientiousness; extraversion; global cognition; HIV-associated neurocognitive disorder; neuroticism; openness

### Background and introduction

Up to 50% of adults with human immunodeficiency virus (HIV) suffer from some degree of HIV-Associated Neurocognitive Disorder (HAND) that may compromise everyday functioning such as driving, medication adherence, and financial management (Bonnet et al., 2013; Cody & Vance, 2016; Heaton et al., 2010). HAND represents a spectrum of cognitive impairment ranging from mild to more severe impairment with deficits observed in at least two or more cognitive domains (Cody & Vance, 2016). As people age with HIV, evidence suggests such cognitive impairments may become more prevalent and severe (Vance et al., 2013). This phenomenon represents a significant public health concern, particularly because over half of people living with HIV (PLWH) in the United States are 50 years and older (CDC, 2018).

Many factors are associated with cognitive impairments in adults with HIV. HIV itself, even when well controlled with combination antiretroviral therapy (cART), creates a systemic low-grade inflammatory response that can also cause neuroinflammation, thus damaging neurons and

compromising cognitive function (Cody & Vance, 2016). Lifestyle behaviors (e.g., substance use, physical exercise) may also impact cognitive function (Fazeli et al., 2011). Metabolic disorders (e.g., diabetes), psychiatric disorders (e.g., depression, anxiety), and other comorbidities (e.g., hepatitis C) are also more prevalent in PLWH and have been shown to negatively affect cognitive functioning (Alford & Vera, 2018; Fazeli et al., 2014; Rubin & Maki, 2019). Yet, such factors only explain part of the variance in cognitive functioning in this clinical population. One potential factor seldom examined is personality.

Personality traits characterize patterns of feeling, thinking, and behaving. The “big five” major dimensions of personality (openness, conscientiousness, extraversion, agreeableness, and neuroticism) have shown associations with cognitive outcomes (performance in individual domains as well as impairment) in middle-aged and older adult populations (Curtis et al., 2015; Soubelet & Salthouse, 2011), in both cross-sectional and longitudinal studies. Higher agreeableness, the disposition to be altruistic and trusting, is associated with better verbal learning, attention/

working memory, executive functions/reasoning, and reaction time (Aiken-Morgan et al., 2012; Graham & Lachman, 2012; Williams et al., 2010). Conscientiousness, the disposition to be vigilant, disciplined, and organized, has shown mixed associations, with some studies finding high conscientiousness is associated with better memory, overall cognitive status (Luchetti et al., 2016), reduction of cognitive decline, lower incidence of mild cognitive impairment (Wilson et al., 2007), and dementia (Aschwanden et al., 2021), while other studies have found no association (Booth et al., 2006; Soubelet & Salthouse, 2011). Higher neuroticism, the disposition for negative affect and emotional dysregulation, has shown associations with poorer memory (Boyle et al., 2010); (Meier et al., 2002); (Williams et al., 2010), as well as with greater risk of cognitive impairment (Crowe et al., 2006) and dementia (Aschwanden et al., 2021; D'Iorio et al., 2018); cf. (Baker & Bichsel, 2006; Jelicic et al., 2003). Higher extraversion, the disposition to focus on others, be social, seek excitement, and have high energy, has been associated with worse performance on tasks of effortful processing, such as reasoning and verbal fluency (Graham & Lachman, 2012; cf. Sutin et al., 2019), but better performance in speed, attention, and executive tasks (Pearman, 2009; Sutin et al., 2019). Lower and moderate extraversion has also demonstrated associations with better cognitive status and less cognitive decline (Crowe et al., 2006; Luchetti et al., 2016) and dementia (D'Iorio et al., 2018). Finally, higher openness, the disposition for trying new things and being creative, has shown associations with better verbal memory and executive functioning (Aiken-Morgan et al., 2012; Sharp et al., 2010; Soubelet & Salthouse, 2011; Williams et al., 2010), while low openness has been associated with dementia risk (D'Iorio et al., 2018). Studies have also shown associations with combinations of personality traits and cognitive decline. High neuroticism and low conscientiousness show consistent associations with cognitive decline and increased risk of dementia (Terracciano & Sutin, 2019). Similarly, low extraversion and high neuroticism also predict future cognitive impairment (Crowe et al., 2006). Another study found that low neuroticism and high agreeableness and conscientiousness were associated with better cognitive performance, as was high extraversion and openness (Baek et al., 2016). In summary, studies have shown associations between all of the big five personality traits with various cognitive outcomes, with small to medium effect sizes. The overall pattern of findings suggests that higher openness, conscientiousness, agreeableness, and lower neuroticism are associated with better cognitive outcomes, while extraversion has shown mixed positive and negative associations. Despite consistent patterns, not all studies examined all personality traits or performance across all cognitive domains, making it difficult to compare across studies, and no studies examined this topic in PLWH.

Several studies demonstrate neurobehavioral pathways linking personality to cognition. Personality traits may promote behaviors that either positively or negatively stimulate the brain, which may in turn affect cognition. Personality traits associated with seeking mental stimulation (i.e., high openness), forming enriching relationships (i.e., high

agreeableness, high extraversion) and engaging in health habits (i.e., high conscientiousness) may create an enriched environment to support brain plasticity, a concept supported by the Openness-Fluid-Crystallized-Intelligence (OFCI) model (Ziegler et al., 2015). Yet, personality traits associated with social isolation (i.e., low extraversion, low openness, low agreeableness) and greater emotional distress (i.e., high neuroticism) hold the potential to stimulate the hypothalamus-pituitary-adrenal axis, elevating cortisol and inflammation levels that over time are neurotoxic to the brain, impairing cognition (Sartori et al., 2012). Yet, it is important to note that associations between personality and brain/cognitive functioning may be bidirectional, and that shared neural substrates may impact both personality and cognition. For example, neurodegenerative disorders such as dementia are associated with large changes in personality over the course of the disease (Islam et al., 2019).

Previous studies have assessed personality within the scope of HIV, finding that personality traits such as high neuroticism and low conscientiousness were related to risk behaviors (Trobst et al., 2000). Higher neuroticism and lower extraversion have also shown associations with poorer quality of life in PLWH (Penedo et al., 2003; Rzeszutek & Gruszczyńska, 2018). Higher conscientiousness has demonstrated associations with better HIV disease management and coping, whereas lower conscientiousness has been linked to depression and stress (O'Cleirigh et al., 2007). Higher conscientiousness, openness, and extraversion were also associated with slower disease progression over time (Ironson et al., 2008). One study in PLWH found that grit, considered a trait reflecting perseverance, passion for goals, and maintenance of effort despite adversity, was associated with better cognitive and everyday functioning (Moore et al., 2018). However, no previous studies to our knowledge have examined the big five personality traits and cognition among PLWH.

Given the demonstrated association between personality traits and cognitive outcomes, including cognitive impairment, in aging populations, such associations may be relevant in predicting cognitive functioning in PLWH, a population at risk for poorer cognitive outcomes. If such personality traits are useful in predicting those at risk for developing cognitive impairments and cognitive decline, this would have implications for both identifying individuals that can be targeted for early intervention as well as development of such interventions. Thus, the purpose of this exploratory study was to examine the relationship between the main five personality traits and cognitive functioning in a sample of middle-aged and older adults with HIV. Given that associations between personality traits and individual cognitive domains have differed in prior studies (and many studies did not examine performance across all domains) and that there is a lack of previous studies examining these associations in PLWH, we used an extensive cognitive battery to examine the relationship between the big five personality traits and a variety of cognitive outcomes, including cognitive impairment status and global and domain-specific cognitive performance.

## Methods

### Design

A secondary data analysis was performed on baseline cross-sectional data obtained from participants ( $N = 261$ ,  $n = 152$  with cognitive impairment; see the Cognitive Functioning section for further detail on classification methods for cognitive impairment) in a randomized controlled trial sponsored by the National Institute of Mental Health (grant number 1R01MH1066366-01). The primary study was designed to investigate the efficacy of a cognitive training program in middle-aged and older adults with HIV (Vance et al., 2017). This study was conducted at an academic health science center in the southeastern United States where it received Institutional Review Board (IRB) approval for the ethical treatment of human subjects. The purpose of this secondary analysis was to investigate the possible associations between personality traits and cognition.

### Participants and procedures

Participants for the primary study were recruited via word of mouth and flyers at a university-based HIV/AIDS clinic. Participants were telephone screened to determine if they met basic self-reported eligibility criteria. Inclusion criteria for the study included being: (a) 39 years or older; (b) English speaking; (c) diagnosed with HIV for at least 1 year; (d) reside within 60 miles of the research facility; and (e) a current licensed driver or able to drive, as driving is a variable of interest in the larger parent study. Exclusion criteria included: (a) being homeless or not in stable housing as the parent study is a longitudinal study requiring multiple follow-up visits and the ability to stay in contact with participants; (b) having a significant neuromedical comorbidity that could compromise cognitive functioning (i.e., schizophrenia, bipolar disorder, Alzheimer's disease, dementia, mental retardation, history of stroke); (c) having brain trauma with loss of consciousness greater than 30 minutes; (d) currently undergoing radiation or chemotherapy; and/or (e) being legally blind or deaf. Many of these exclusion criteria were necessary as they can impact cognitive assessment and confound the association between HIV and cognition. Once appropriately screened, eligible candidates were brought into the lab for the collection of baseline data to which the current analysis refers.

### Instruments

#### Demographic questionnaire

The questionnaire included basic demographic information such as age, gender, race/ethnicity, household income, occupation, work-status, highest level of education completed, and marital status.

#### Depression questionnaire

The Center for Epidemiological Studies Depression Scale (Radloff, 1977) was used to assess depressive

symptomology, with scores of 16 or greater categorized as clinically relevant.

#### Medical history

Personal health information and comorbid medical conditions and HIV indicators (including most recent viral load, CD4 count, nadir CD4 count) were collected. A urine sample was collected to determine substance use status on the day of the study visit for the following substances: amphetamines, methamphetamines, opiates, THC, and cocaine. As participants were recruited from the HIV/AIDS clinic, they were additionally asked to sign a release of information so that clinical lab values could be obtained.

#### Big Five Inventory (BFI)

The BFI is a brief subjective questionnaire developed to measure the five dimensions of personality in accordance with the five-factor model of personality: openness (e.g., *is curious about many different things*), conscientiousness (e.g., *does a thorough job*), agreeableness (e.g., *is generally trusting*), extraversion (e.g., *is outgoing, sociable*), and neuroticism (e.g., *worries a lot*). The BFI consists of 44 short phrases of relatively accessible vocabulary and responses are scored on a 5-point Likert scale to indicate the degree of applicability each phrase has to the participant (i.e., *disagree strongly, disagree a little, neither agree or disagree, agree a little bit, agree strongly*). The participant's answers are tallied according to a key, which produces a numerical score for each trait with potential scores ranging between 8 and 50 (Benet-Martínez & John, 1998; John et al., 1991; John et al., 2010). For visual representation of scores in Table 1 in order for scores to be on the same scales, we transformed scores to a percentage of maximum possible (POMP) score where 0 represents the minimum possible score and 100 represents the maximum possible score. Specifically, we transformed the 1-to-5 BFI metric into POMP scores by subtracting 1 and multiplying by 25. Sample means and standard deviations, in POMP units, were as follows for Americans between 20 and 60 years old in a large study ( $N = 132,515$ ): Conscientiousness 63.8 (8.3); Agreeableness 66.4 (18.0); Neuroticism 51.0 (21.9); Openness 74.5 (16.4); Extraversion 54.6 (22.6) (Srivastava et al., 2003). The BFI has established reliability in multiple populations including English ( $\alpha = 0.85$ ) and Spanish ( $\alpha = 0.78$ ); (Benet-Martínez & John, 1998), as well as in clinical populations, such as psychopathology (alphas ranging from 0.784 to 0.863; (Mirnics et al., 2013), cancer (alphas ranging from 0.64 to 0.83; (Villaron et al., 2017), and rheumatic diseases ( $\alpha = 0.74$ ; (Bucourt et al., 2017). The BFI also shows convergent validity with the NEO Personality Inventory (Benet-Martínez & John, 1998; Soto & John, 2009). In the current study, average Cronbach's alphas across the 5 domains was 0.70, indicating good internal consistency (Openness = 0.73, Conscientiousness = 0.67, Extroversion = 0.60, Agreeableness = 0.71, Neuroticism = 0.78).

**Table 1.** Demographics and descriptive characteristics of study sample ( $n = 261$ ).

Variables	<i>N</i> (%)	<i>M</i> ( <i>SD</i> )	Range
Male	168 (64.37)		
Non-White	216 (82.76)		
Age (years)		51.1 (6.88)	39–73
Education (years)		12.53 (2.24)	7–20
Income (annual)			
\$0.00–20k	206 (78.92)		
\$20k–40k	36 (13.79)		
\$40k–60k	10 (3.83)		
\$60k–80k	4 (1.53)		
\$80k+	5 (1.92)		
Unemployed	204 (78.16)		
Nadir CD4 <sup>+</sup> <sup>a,b</sup>		192.00 (25.75–465.00)	1–1,192
Current CD4 <sup>+</sup> <sup>c</sup>		659.84 (376.09)	10–1,839
Detectable viral load <sup>d</sup>	72 (33.65)		
ART status (on) <sup>e</sup>	231 (95.00)		
Urine toxicology (+)	107 (42.13)		
CES-D		17.95 (11.00)	0–49
Cognitive impairment	152 (58.24)		
Global Cognitive T-Score		44.53 (6.01)	28.13–61.19
Verbal fluency		45.90 (7.80)	26.00–72.33
Executive function		46.11 (8.94)	20.00–72.00
Speed of processing		47.44 (8.18)	25.00–69.33
Learning		42.43 (7.55)	21.50–66.50
Recall		43.19 (7.93)	16.50–65.50
Working memory		44.89 (9.00)	19.00–73.00
Motor skills		39.42 (8.91)	9.00–64.00
Personality traits			
Openness		64.75 (15.48)	27.50–100.00
Conscientiousness		72.12 (15.19)	25.00–100.00
Extraversion		57.74 (15.64)	15.63–100.00
Agreeableness		77.10 (15.60)	27.78–100.00
Neuroticism		45.79 (20.29)	0.00–100.00

Note. CES-D = Center for Epidemiological Studies-Depression Scale. <sup>a</sup> Median and interquartile range reported; Of Nonwhite participants, 97% were African American.

<sup>b</sup> $n = 238$ .

<sup>c</sup> $n = 185$ .

<sup>d</sup> $n = 214$ .

<sup>e</sup> $n = 244$ .

### Cognitive functioning

A battery of clinical cognitive measures was completed by participants to assess verbal fluency (Controlled Oral Word Association Test [letters FAS] and Animal and Action Fluency), executive function (Wisconsin Card Sorting Task and Trail Making Test Part B), speed of processing (Trail Making Test Part A and Wechsler Adult Intelligence Scale—Third Edition (WAIS-3) Digit Symbol and Symbol Search), learning and recall (two domains, Hopkins Verbal Learning Test—Revised and Brief Visuospatial Memory Test—Revised), working memory (Paced Auditory Serial Addition Test 2000 and WAIS-3 Letter Number Sequencing, and motor skills (Grooved Pegboard—dominant and nondominant hands). Demographically adjusted (for age, education, gender, and race/ethnicity, when available) cognitive test scores were converted to global cognitive T-scores as well as domain T-scores across the seven domains. Using standard algorithms, these T-scores were converted to clinical ratings. Additional information regarding standard clinical ratings can be found elsewhere (Carey et al., 2004; Woods et al., 2004). For the purposes of this study, cognitive impairment was defined by a global clinical rating score of five or greater (which is analogous to a T-score of  $< 40$ ). This cognitive impairment variable reflects meeting the minimum criteria for HAND (i.e., having at least asymptomatic

neurocognitive impairment [ANI]), which requires at least two domains in the mildly impaired range (i.e., at least 1 standard deviation below the mean). Continuous t-scores (of individual cognitive domains as well as global cognition) and cognitive impairment status were each examined in analyses.

### Data analysis

We first conducted bivariate analyses (Pearson's correlations or *T*-tests) between each personality trait and cognitive outcome (i.e., cognitive impairment status and global and domain T-scores). We then conducted additional bivariate analyses (Pearson's correlations, *T*-tests, or Chi-square test, whenever appropriate) to determine conceptually related clinico-demographic variables (from Table 1) that were associated with either personality or cognition that should be considered as covariates in subsequent analyses. We applied the Benjamini-Hochberg false discovery rate (FDR) procedure to adjust p-values from multiple tests for each series of bivariate analyses (Glickman et al., 2014). A total of 106 of p-values were included in the adjustment procedure (38 were significant prior to adjustment, while 26 remained significant after FDR adjustment). We considered "significance" at an FDR of 0.1 (Efron & Hastie, 2016), and all reported p-values are after FDR correction. Finally, hierarchical multiple linear regression was used to examine correlates of global T-scores, entering clinico-demographic covariates in block 1 and personality traits in block 2.

### Results

As seen in Table 1, participants were 39–73 years old. The majority of participants were nonwhite (80% of the sample was African American, while 17% were White,  $< 1\%$  were either Hispanic or Asian, while 2% reported "Other") and male with on average 12 years of education and largely unemployed with annual incomes less than \$20,000. Approximately 58% exhibited some degree of global cognitive impairment. The average CD4<sup>+</sup> T lymphocyte count was 659.84 cells/mm<sup>3</sup>, 66% of participants exhibited an undetectable HIV viral load, and 42% had positive urine toxicology results. BFI personality traits and cognitive functioning T-scores are presented in Table 1.

None of the five personality traits as measured by the BFI were significantly associated with cognitive impairment status (Cohen's *d* range = 0.01–0.22;  $ps > 0.05$ ). However, several associations were found between traits and global and individual domain T-scores (Table 2) with correlations of small-to-moderate magnitude. Specifically, higher openness was positively associated with better global T-scores ( $r = 0.27$ ) and better performance in all cognitive domains ( $r$  range = 0.18 for working memory to 0.28 for verbal fluency) except executive function and motor skills ( $r = 0.13$  and 0.10, respectively). Higher conscientiousness was positively associated with better performance in speed of information processing ( $r = 0.19$ ) but not with other domains ( $r$  range = 0.03 for executive function to 0.13 for motor skills) or global functioning ( $r = 0.13$ ). Higher agreeableness was

**Table 2.** Correlation table.

	O	C	E	A	N
	r(p-value)				
Global cognition	<b>0.27, &lt;0.01</b>	0.13, 0.05	0.05, 0.39	<b>0.21, &lt;0.01</b>	-0.07, 0.25
Verbal fluency	<b>0.28, &lt;0.01</b>	0.08, 0.19	0.10, 0.12	<b>0.16, 0.01</b>	-0.06, 0.33
Executive function	0.13, 0.04	0.03, 0.66	0.06, 0.35	0.12, 0.05	-0.08, 0.20
Speed of processing	<b>0.24, &lt;0.01</b>	<b>0.19, &lt;0.01</b>	0.12, 0.06	<b>0.26, &lt;0.01</b>	-0.10, 0.10
Learning	<b>0.19, &lt;0.01</b>	0.03, 0.59	-0.09, 0.17	0.12, 0.06	0.01, 0.82
Recall	<b>0.21, &lt;0.01</b>	0.07, 0.28	-0.05, 0.45	<b>0.14, 0.03</b>	-0.03, 0.67
Working memory	<b>0.18, &lt;0.01</b>	0.06, 0.32	0.02, 0.75	0.08, 0.20	-0.03, 0.61
Motor skills	0.10, 0.13	0.13, 0.03	0.04, 0.52	<b>0.15, 0.02</b>	-0.04, 0.57
Openness	1.00	-	-	-	-
Conscientiousness	<b>0.36, &lt;0.01</b>	1.00	-	-	-
Extraversion	<b>0.25, &lt;0.01</b>	<b>0.26, &lt;0.01</b>	1.00	-	-
Agreeableness	<b>0.33, &lt;0.01</b>	<b>0.26, &lt;0.01</b>	<b>0.31, &lt;0.01</b>	1.00	-
Neuroticism	-0.14, 0.03	<b>-0.39, &lt;0.01</b>	<b>-0.24, &lt;0.01</b>	<b>-0.27, &lt;0.01</b>	1.00

Notes: O = Openness; C = Conscientiousness; E = Extraversion; A = Agreeableness; N = Neuroticism. Associations that were significant after the 10% False Discovery Rate procedure are in bold text.

associated with better global T-scores ( $r=0.21$ ) as well as better performance in verbal fluency ( $r=0.16$ ), speed of information processing ( $r=0.26$ ), recall ( $r=0.14$ ), and motor skills ( $r$  range for nonsignificant domains = 0.08 for working memory and 0.12 for executive function and learning). Extraversion and neuroticism were not significantly associated with any cognitive outcomes ( $r$  range = 0.02 for working memory to 0.12 for speed of processing and 0.01 for learning to  $-0.10$  for speed of processing, respectively).

Given that openness and agreeableness were the traits most consistently associated with cognitive functioning (individual cognitive domains as well as global T-scores), we included these in a hierarchical linear regression model predicting global T-scores. After FDR correction, income, age, education, and depression met the qualification to be entered as covariates in the regression model, as they were significantly associated with either openness (age, income, education) agreeableness (depression), or global T-scores (income). Collinearity statistics among these covariates, as well as the two personality traits, indicated no substantial collinearity (all Tolerance values  $>0.4$  and Variance Inflation Factor [VIF]  $<2.5$ ). This hierarchical regression model showed that each block explained a small-to-moderate proportion of the variance of global T scores. Block 1, with clinico-demographic covariates only, explained 5.7% of the variance in global T scores. The addition of personality variables (i.e., openness and agreeableness) to the model in block 2 explained 6% additional variance ( $R^2$  change from Block 1 to Block 2 = 0.06) in global T-scores beyond clinico-demographic factors. In the Block 2 model containing all variables, income and openness were the only significant ( $p$ -values  $<0.01$ ) correlates of global T-scores and had the largest standardized coefficients (Table 3). Finally, we conducted an identical model with the exception that all five BFI traits were entered in Block 2 (i.e., same Block 1 variables while Block 2 examined all five BFI traits), and the pattern of results remained unchanged (i.e., openness was the strongest predictor of global T-scores).

## Discussion

As roughly 50% of PLWH will develop some degree of HAND, the goal of the current study was to determine the

**Table 3.** Hierarchical linear regression model (Block 2).

Variables	Dependent variable: global T-score					
	B (SE)	Standardized $\beta$	p value	Lower CI	Upper CI	VIF
Openness	0.19 (0.07)	0.20	$<0.01$	0.06	0.33	1.30
Agreeableness	0.13 (0.07)	0.12	0.06	-0.01	0.27	1.18
Education	-0.11 (0.19)	-0.04	0.57	-0.48	0.27	1.40
Age	0.05 (0.06)	0.05	0.40	-0.06	0.15	1.05
Income	0.64 (0.23)	0.19	$<0.01$	0.19	1.10	1.29
Depression Score	-0.00 (0.04)	-0.00	0.95	-0.07	0.07	1.13

Note. B = Beta; CI = Confidence Interval; SE = Standard Error; VIF = Variance Inflation Factor.  $F=5.45$ . Degrees of Freedom (6, 242). Model  $p$ -value =  $<0.01$ ;  $R^2 = 0.12$ ; Adjusted  $R^2 = 0.10$ ;  $R^2$  Change from Block 1 to Block 2 = 0.06.

relationship between personality traits and cognitive functioning in this population. No associations emerged between cognitive impairment status and personality traits. However, examining the cognitive data continuously, there were associations between specific traits and individual cognitive domains as well as with global cognitive functioning. The most robust finding was that even in the context of clinico-demographic factors such as age, socioeconomic status (SES) factors (i.e., income and education), and depression, openness had an independent association with global cognitive functioning. Furthermore, even when including all five traits in the model, openness remained the only personality trait to emerge as a predictor. The association between openness and cognition in adults aging with HIV is consistent with other published reports in the literature on nonpathological aging (Schaie et al., 2004; Sutin et al., 2019).

Previous studies demonstrating that openness is related to cognitive functioning offer several potential mechanisms whereby higher levels of this trait may contribute to better cognitive functioning. All of these theories converge on the general notion that more open individuals are more likely to seek out new and stimulating experiences and activities that ultimately facilitate learning throughout the lifespan. For example, the Openness-Fluid-Crystallized-Intelligence (OFCI) Model (Ziegler et al., 2015), which combines environmental enrichment and investment theories, proposes that more open individuals are more likely to encounter new opportunities for learning that has a positive effect on crystallized intelligence via fluid intelligence (i.e., mediation),

which ultimately buffers against cognitive decline. The OFCI Model also has a bidirectional component, such that higher fluid intelligence throughout the lifespan is a contributor to being higher in openness. Other work supports this model, showing that associations between openness and cognitive functioning are mediated by educational attainment, cognitive complexity of one's job, and leisure activities (Ihle et al., 2016). The principles supporting this model are also exemplified beyond the aging literature. Children and young adults with high openness scores exhibit greater intrinsic motivation to read, interest in more challenging reading material, greater intellectual curiosity, and are more eager to learn (Sutin et al., 2019; Zhou, 2019). All of these studies ultimately suggest that more open individuals are more likely to seek out experiences and environments that may bolster their cognitive reserve, positioning them to better compensate for cognitive insults. While future studies should explore the potential mechanisms whereby higher openness influences cognitive functioning in PLWH, the current study found that even when adjusting for educational attainment (and income), higher openness was associated with better cognitive functioning, suggesting that indeed other factors may mediate this association.

Though openness was found to be independently associated with cognitive functioning, it is worth noting that a large portion of our sample had low SES and that openness was related to education and income. Being that higher openness is associated with higher educational attainment, greater learning and intellectual abilities, and jobs with higher cognitive engagement, people from low SES backgrounds may not readily have access to these opportunities. As such, screening for individuals with low openness scores may signal those who may be less likely to seek out mentally stimulating activities on their own and may be ideal targets for cognitive interventions. Even among those with high openness, providing opportunities for cognitive enrichment may be an ideal intervention target. Nonetheless, the independent association we found between openness and cognitive functioning even in such a low SES group suggests that these individuals with higher openness may be engaging in stimulating activities despite their SES and, furthermore, that there may be other pathways whereby openness influences cognitive functioning.

Agreeableness and conscientious were the only other personality traits identified to have correlations to cognitive domain functions, although these did not remain in the context of openness. This finding supports previous findings in the literature; as these two personality traits have previously been associated with higher levels of cognition (Aiken-Morgan et al., 2012; Graham & Lachman, 2012; Luchetti et al., 2016; Williams et al., 2010; Wilson et al., 2007). Interestingly, this study does not support previous studies showing that high scores of neuroticism typically have a negative association with cognition (Baek et al., 2016; Schaie et al., 2004), nor did this study align with prior work demonstrating associations with extraversion and cognition (Crowe et al., 2006; Graham & Lachman, 2012; Pearman, 2009). Several possibilities are posited for why we found

fewer and different associations between personality and cognition than prior studies. First, unlike other studies that examined nonclinical samples without known cognitive impairments, approximately half of this sample of adults with HIV experienced cognitive impairment (defined as impairment in at least two cognitive domains). As previously mentioned in the OFCI model, there is likely a bidirectional association between personality and cognitive function, and, as such, cognitive deficits may alter personality in clinical populations, resulting in incongruent associations than those typically reported in the literature. While we did not find associations between any traits and cognitive impairment status this could have been due to dichotomizing functioning, obscuring potential associations. Further, several prior studies found associations between traits and cognitive decline or development of cognitive impairment over time, which was not possible in the current cross-sectional study. Second, our sample of mostly African Americans and men from lower SES backgrounds in the Deep South may have experienced a more stressful environment, greater stigma, and social adversity; such factors can stimulate the hypothalamus-pituitary-adrenal axis that over time could elevate systemic and neuronal inflammation that impairs cognition (Obasi et al., 2020; Sartori et al., 2012). For example, in the Williams et al. (2010) study where the connection between openness, neuroticism, and agreeableness with executive function was observed, the study was conducted in Utah, with a sample that had higher levels of formal education than our sample. Additionally, although race was not reported, the sample likely lacked racial diversity, given that approximately 90% of Utah is White (US Census Bureau, 2019). Given what is known about the relationship between social determinants of health and cognitive health (Crowe et al., 2013), potential interactions between environmental stressors, cultural context, and hypothalamus-pituitary-adrenal axis function may have obscured some associations in our study. From all of these points, we can surmise that the few personality-cognition association that were detected may be particularly robust.

Another consideration of the study findings concerns effect sizes. The cross-sectional effect size between openness and global cognition ( $r = 0.266$ ;  $\beta = 0.19$ ) was similar to that observed between openness and cross-sectional memory (Luchetti et al., 2016) and executive function (Williams et al., 2010) performance in other studies. In general, the effect sizes are small-to-medium; however, the health behaviors related to personality may obscure any association between personality traits and cognition. In other words, the relationship between personality traits and mediating behaviors may be stronger in PLWH and warrants further study. Additionally, the downstream effects on cognition may be smaller, yet these differences still may be clinically meaningful. Indeed, in our multiple regression analysis, education level, a commonly used proxy for cognitive reserve, which is a widely regarded predictor of cognitive functioning across many populations (Meng & D'Arcy, 2012; Stern & Barulli, 2019; Zieren et al., 2013), had a lower effect size than openness. Interestingly, as observed by Sutin et al. (2019) in a 10

cohort study, the effect sizes between personality and cognition seem to be larger in cognitively vulnerable groups, specifically older individuals and those with lower levels of education; this holds partially true in this low SES sample of middle-age and older adults with HIV. Furthermore, a common predictor of cognitive functioning in PLWH is depressive symptoms, with effect sizes ranging from small to medium (Paolillo et al., 2020); yet in our sample of which over half had clinically relevant depression scores, depression was not a significant correlate of global cognitive T scores, with a regression coefficient of zero.

### **Strengths and limitations**

This study has many strengths. First, this study incorporated all five major personality traits as well as a comprehensive gold-standard cognitive battery that assessed performance in several domains. Therefore, this study provided a more complete examination of the relationship between personality traits and cognition in PLWH. Second, personality scores were comparable to those found in a large study of Americans between 20 and 60 years ( $N=132,515$ ; Srivastava et al., 2003), supporting the generalizability of our findings. However, although a strength of this study was the use of a sample of HIV+ participants who exhibited a wide range of cognitive function and the rate of cognitive impairment found in our sample is consistent with the rates of cognitive impairment/HAND observed in the literature among people with HIV (i.e., rates as high as 50%; Heaton et al., 2010), our results may not generalize to HIV populations (e.g., younger individuals) with higher cognitive functioning.

Likewise, this study had several limitations. First, this study was not longitudinal. While cross-sectional findings are informative, persons with progressing cognitive impairment may exhibit some changes in personality over time (Caselli et al., 2018). For example, neuroticism scores have been shown to increase as cognition declines (Waggel et al., 2015). A longitudinal study would allow for assessing the direction of any potential correlations between personality traits and the rate of cognitive decline over time. Indeed, we did not find associations between personality traits and cognitive impairment status, yet longitudinal work may detect associations between specific traits and development of cognitive decline over time. Second, while we did consider urine toxicology on the day of the study visit as a potential covariate (which was not associated with personality or cognition), a more comprehensive assessment of substance use was not included in this study. Personality traits have been shown to predict propensity of risk for developing a substance use disorder, substance use pattern, and specific negative consequences of bingeing behavior (Dash et al., 2019; O'Leary et al., 2019; Sutin et al., 2013; Terracciano et al., 2008). As this population has been estimated to experience an approximate 48% prevalence rate of substance use disorders, future studies should include such comprehensive substance use assessments to disentangle associations between personality traits and substance use disorders, as well as how these interplay to affect cognitive functioning (Hartzler

et al., 2017). Third, our results may have been influenced by several unique demographic and cultural characteristics of our sample, which took place in the Deep South with a predominantly African American sample with low SES. Fourth, a selection bias in the present study represents a potential limitation. Openness to experience would likely also affect the willingness to be participants in research studies; thus, our sample may have represented a group with overall higher openness than the overall population of PLWH. Finally, given the exploratory nature of this study, a number of analyses were performed, increasing risk for Type I error, in a sample that was underpowered to detect small associations. Yet our analytic approach attempted to minimize such limitations, and, furthermore, our pattern of results, specifically effect sizes, were consistent with prior work.

### **Conclusion**

This study investigated the association between cognitive function across seven domains and the five major dimensions of personality. We found that even when considering important confounders, higher scores in the personality trait of openness were associated with better global cognition. Potential mechanisms proposed in the gerontological literature for such associations suggest that having greater openness to experience leads to a more enriched environment, thereby creating more opportunities for improving and protecting cognitive functioning (Cody & Vance, 2016). Future studies are warranted to directly examine mechanisms whereby personality is associated with cognitive function in people with HIV, which may ultimately inform future intervention strategies.

### **Implications for research and practice**

The relationship between personality and cognitive outcomes among PLWH warrants further investigation. While the results of this study are useful, several avenues for research remain. Future research is needed to identify the mechanisms whereby personality traits are related to cognitive functioning in this population, including both behavioral (e.g., HIV disease management, lifestyle activities, substance use) and neural pathways. Additionally, studies should consider the role that genetic factors may play on development of personality traits in people living with HIV, as previous studies have demonstrated that genetic variations are associated with certain personality traits, particularly neuroticism (Okbay et al., 2016; Sanchez-Roige et al., 2018) and extraversion (Lo et al., 2017; Stein et al., 2017). Longitudinal data are needed to investigate the role of the pathological process that HAND and individual personality profile exert on each other. Additionally, the results of this study suggest that future work should develop strategies for identifying those PLWH with low openness and developing intervention strategies to bolster positive behaviors reflected by this personality trait. Furthermore, individuals with lower openness scores may need earlier and more frequent comprehensive cognitive assessment.

## Disclosure statement

The authors report no real or perceived vested interest that relate to this article that could be construed as a conflict of interest.

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## ORCID

Pariya L. Fazeli  <http://orcid.org/0000-0001-6629-0010>

John D. Cheatwood  <http://orcid.org/0000-0002-9058-805X>

David E. Vance  <http://orcid.org/0000-0002-0498-6263>

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