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Grit and Ambition are Associated with Better Neurocognitive and Everyday Functioning Among Adults Living with HIV

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Abstract

Grit and ambition are psychological factors that may protect neurocognitive function among persons living with HIV (PLWH). We examined associations between grit, ambition, premorbid verbal intellectual function, and current neurocognitive and everyday functioning among PLWH and persons without HIV (HIV−). 120 PLWH and 94 HIV− adults completed the Grit Scale (includes total score and consistency of interests and perseverance of effort subscales), ambition scale, and a comprehensive neurobehavioral battery. PLWH had lower grit scores than HIV− adults. The two groups did not differ on ambition. No relationship was observed between grit and cognition among HIV− adults. Among PLWH, however, higher perseverance of effort and more ambition was related to better global neurocognitive functioning, and higher grit, but not ambition, was related to independence in daily functioning. Longitudinal studies are needed to elucidate these relationships over time and examine whether grit or ambition have protective effects on cognitive outcomes among PLWH.

Keywords Hardiness · Cognitive reserve · AIDS · Aging · Functional dependence

Introduction

With the introduction of combination antiretroviral therapy (cART), the lifespan of persons living with HIV (PLWH) who have access to adequate health care is nearly comparable to that of people who do not have HIV [1]. Despite successful virologic suppression via cART, neurocognitive deficits, referred to as HIV-Associated Neurocognitive Disorders (HAND), persist, and affect over 50% of PLWH [2]. HAND is known to adversely affect everyday functioning, including employment rates, medication adherence [3, 4], instrumental activities of daily living (IADLs) [5, 6], and driving ability [7, 8], as well as health-related quality of life [5, 9], and is a risk factor for increased mortality [10]. Although the rates of neurocognitive impairment among PLWH are high and the negative consequences of neurocognitive impairment for worse daily functioning are many, there are a broad range of neurocognitive functioning among PLWH. In fact, recent studies show that there is a subgroup of PLWH who are successfully cognitively aging—i.e., with neurocognitive performance and appraisals similar to that of age-comparable people without HIV [11, 12], and that other factors beyond the direct impact of HIV infection on the central nervous system may impact neurocognitive health in this population.

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Cognitive reserve is the concept that there are individual differences in flexibility and adaptability of the brain to accommodate after neural insult and that these differences are related to pre-existing cognitive processes and neural networks [13]. Individuals with higher cognitive reserve have better compensatory mechanisms compared to individuals with lower cognitive reserve, particularly when they are faced with neurological insult [14]. Cognitive reserve is also dependent upon a person's exposure to positive neuroplastic events, such that people engaged in cognitively demanding tasks, in enriched environments, and with novel stimuli throughout the lifespan accumulate stronger neuronal connections (i.e., greater cognitive reserve) [15].

The specific underlying cognitive mechanisms that influence cognitive reserve among PLWH are not fully understood. At present, most research uses traditional measures of premorbid intelligence and academic achievement, such as IQ and level of education, to serve as proxies for cognitive reserve, though these do not account for total variability in cognitive functioning [16]. Thus, recent work has begun to expand cognitive reserve to include paradigms involving positive psychological factors such as perseverance, resilience, motivation, and grit [17–19]. These non-cognitive factors have been referred to in the literature as reserve capacity [20, 21]. Reserve capacity includes a series of psychological and psychosocial factors. In this study, we examined the role of grit as a potentially “psychological reserve” factor (i.e., a non-cognitive reserve capacity factor without a psychosocial component) that may influence cognition and everyday functioning among PLWH.

Grit, defined as perseverance and passion for long-term goals, with an emphasis on stamina and maintenance of effort despite adversity, is an attribute that has shown utility in helping understand individual differences that predict success and cognition in normal aging populations [17, 19]. Duckworth et al. [17.] postulated that personal achievement is obtained in two phases: (1) talent multiplied by effort (i.e., grit) leads to skill, then (2) skill multiplied by effort (i.e., grit) leads to achievement. Thus, it is proposed that grit not only builds skill, but is also modifiable and additionally, contributes to productivity. During development of the Grit Scale, it was found that grit predicted successful outcomes (i.e., education attainment, retention in a rigorous training program, fewer career changes, and vocational/avocational advancement) above and beyond what was explained by IQ [17]. Although these types of successful outcomes represent one aspect of functioning, to our knowledge, no published study has assessed the relationship between grit and more specific everyday adaptive functioning abilities such as independence in completing instrumental daily living activities (IADLs; e.g., managing finances, preparing meals, using transportation, etc.), which, as mentioned above, can decline with HIV infection and aging.

Ambition is a concept that is commonly associated with grit. In contrast to grit, which is a trait that does not require immediate positive feedback nor the short-term accomplishment of goals [17], ambition is defined as a desire to achieve success or power and obtain external recognition for achievements [22]. Some studies have included ambition as a component of grit [23–25]; however, ambition was not included in the original conceptualization of grit [17, 26]. Ambition is a personality trait that can be adaptive and help one flourish, and is perhaps another “psychological reserve” factor that may have an influence on cognition and everyday functioning among PLWH.

Given that PLWH have often had to deal with physical and psychosocial adversity related to living with HIV, grit may be an important non-cognitive, “psychological reserve” factor contributing to the ability to preserve successful cognitive and everyday functioning. Thus, the hypotheses of this exploratory cross-sectional study were: (1) levels of grit would differ between persons with and without HIV infection, such that PLWH would have lower grit; (2) grit would be related to premorbid cognitive functioning, neurocognitive performance, and everyday functioning among adults with and without HIV infection; and (3) there would be an interaction between grit and premorbid IQ on global cognitive functioning among PLWH such that persons with both high grit and high premorbid IQ would have higher global cognitive functioning compared to those with either low grit/high premorbid IQ or high grit/low premorbid IQ. In addition to grit, we also explored the relationship of ambition with cognitive functioning and everyday functioning in an exploratory fashion.

Methods

Participants and Design

Participants were 120 PLWH and 94 persons without HIV, aged 36–65, from the longitudinal *Multi-Dimensional Successful Aging among HIV-Infected Adults* study. Baseline data were examined in this study. The University's Institutional Review Board approved this study, and all participants provided written, informed consent. In order to enroll a representative cohort of participants, exclusion criteria were minimal: (1) diagnosis of a psychotic disorder or mood disorder with psychotic features (asked at screening visit); (2) presence of a neurological condition (beyond HIV infection) known to impact cognitive functioning (e.g., Alzheimer's disease, stroke, traumatic brain injury); (3) positive urine toxicology on the day of testing. An HIV/HCV finger stick point of care test (Abbott Real Time HIV-1 test, Abbott Laboratories, Illinois, USA) was used to test all participants for

HIV infection. Of the participants who reported they were HIV– at screening, none tested positive for HIV nor HCV.

Measures

Grit Scale

Participants completed the 12-item Grit Scale [17, 26], which includes two subscales: Consistency of Interests (6-items) and Perseverance of Effort (6-items). The factor structure was derived through exploratory and confirmatory factor analysis [17]. These two factors of grit were assessed with self-report items such as: “New ideas and projects sometimes distract me from previous ones” (consistency of interests) and “I have overcome setbacks to conquer an important challenge” (perseverance of effort). Responses are rated on a 5-point scale from 1 (*very much like me*) to 5 (*not at all like me*), and reverse coded when indicated, with higher scores representing more grit. Responses are averaged, and subscale scores range from 1 to 5. A total score is also derived by averaging the two subscale scores (range 1–5).

Ambition Scale

Participants also completed a five-item Ambition scale (unpublished). These five items were developed by Duckworth but were never incorporated into the grit concept, grit scale, nor were they validated. There have been some publications including these five items in a “17-item grit scale;” however, they were not originally conceptualized as a subcomponent of grit. We were unable to identify the original source of the “17-item grit scale.” These five items are: (1) I aim to be the best in the world at what I do; (2) I am

ambitious; (3) Achieving something of lasting importance is the highest goal in life; (4) I think achievement is overrated; and (5) I am driven to succeed. Responses are rated on a 5-point scale from 1 (*very much like me*) to 5 (*not at all like me*), reverse coded when indicated, and averaged, with higher scores representing more ambition.

Premorbid Estimate of Intellectual Functioning (IQ)

The Wide Range Achievement Test (WRAT) 4th Edition—reading subtest [27] was used to assess premorbid cognitive reserve. Raw scores were converted to age-corrected normative standard scores (mean = 100, SD = 15). Among PLWH, word reading tests, such as the WRAT, have been found to be valid and stable indicators of premorbid cognitive reserve [28].

Current Neuropsychological and Everyday Functioning Measures

Neuropsychological Battery The HIV Neurobehavioral Research Program (HNRP) Core neuropsychological battery and standardized interpretation algorithms were constructed in accordance with the Antinori [29] and NIMH/NINDS working group guidelines for diagnosing HAND. This standardized battery assesses seven cognitive domains commonly affected by HIV: verbal fluency, working memory, speed of information processing, verbal and visual learning, delayed recall, executive function, and complex motor function. Table 1 contains the individual tests that comprise this battery. Raw scores from the neuropsychological tests were converted to demographically-adjusted for age, education, sex, and race/ethnicity T-scores ($M = 50$, $SD = 10$ in healthy subjects) using the best available nor-

Table 1 Tests in the neuropsychological battery

Cognitive domain	Tests
Speed of information processing	WAIS-III Digit Symbol WAIS-III Symbol Search Trail Making Test, Part A Stroop Color Trial
Learning and memory (2 domains)	Hopkins Verbal Learning Test-Revised Brief Visuospatial Memory Test-Revised
Abstraction/executive functioning	Wisconsin Card Sorting Test (64-item) Trail Making Test, Part B Stroop Color Word Trial
Verbal fluency	Controlled Oral Word Association Test Category Fluency (Animals) Category Fluency (Actions)
Attention/working memory	WAIS-III Letter-Number Sequencing PASAT (1st channel only)
Motor	Grooved Pegboard Test (dominant and non-dominant hands)

WAIS-III: Wechsler Adult Intelligence Scale 3rd Edition; PASAT: Paced Auditory Serial Addition Task

mative standards [5]. T-scores were averaged across tests within each domain to generate a mean T-score. Global continuous T-scores were used in our comparisons of cognition with other variables in this study.

Everyday Functioning Functional dependence versus independence in instrumental activities of daily living (IADLs) was determined using a modified version of the Lawton and Brody scale [5]. The IADL scale is a self-report measure that asks participants to answer questions relating to the level of assistance needed to complete IADLs (i.e., managing finances, using the telephone, cooking, buying groceries, working, transportation, understanding of written and viewed material, social activities and childcare) as they are currently functioning compared to when they were at their highest level of functioning. Participants were considered IADL Dependent if they reported declines in functioning in at least two domains. This IADL classification approach has previously been validated in a normative sample compared to a sample with cognitive impairment [30]. In addition, this self-report measure has been shown to consistently be associated with objective measures of functional dependence in persons with HIV-associated neurocognitive disorders [31].

Potential Confounds: Psychiatric and Substance Use Disorders

To evaluate lifetime and current major depressive disorder and substance use disorders, the Composite International Diagnostic Interview was administered (CIDI, v2.1; [32]). The CIDI is a computer-assisted, fully-structured clinical interview. Diagnostic criteria for the CIDI are based on the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders [33].

Potential Confounds: HIV Disease Characteristics

Among PLWH, severity of HIV disease was characterized by utilizing plasma HIV RNA viral loads, CD4+ T cell counts (nadir and current), duration of HIV disease, and AIDS/non-AIDS classification. The AIDS Clinical Trials Group (ACTG) 4-day medication adherence questionnaire [34] was used to estimate antiretroviral therapy (ART) adherence.

Statistical Analyses

IBM SPSS Statistics for Windows, Version 24 [35] was used for all analyses. Data were screened for outliers and violation of statistical assumptions. First, univariate analysis of covariance models were performed to determine group differences on the grit total score and each of the two subdomains measured on the grit scale (consistency of interests; perseverance of effort) between individuals with and without

HIV infection. Regression models were run to determine the relationships between HIV status, grit/ambition, premorbid IQ (i.e., WRAT scores), and global neurocognitive functioning (i.e., global T-scores). Pearson correlations were performed to examine the relationships between grit/ambition and IADL status (dependence versus independence) among PLWH. Only one of the HIV– participants met criteria for IADL dependence, therefore no analyses with this variable could be conducted in this group.

Next, to determine the clinical correlates of grit that may be impacting the relationships between grit, ambition, neurocognitive functioning, and IADL dependence among PLWH, a series of correlation and Chi square tests were conducted with the variables listed in Table 2 (critical p value set conservatively at 0.05). When correlations were significant, we proceeded to conduct multiple regression analyses to determine if results persisted, above and beyond the influence of covariates, and if any main effects or interactions emerged.

Results

Comparison of Grit and Ambition by HIV Serostatus

Demographic and clinical characteristics of the sample are presented in Table 2. Correlations between grit total score, grit subdomains, and ambition, by group, are presented in Table 3. Univariate analysis of covariance models that controlled for demographic variables that significantly differed between the two groups (sex, race/ethnicity, and education) were conducted to determine whether grit differed by HIV serostatus. PLWH had significantly lower grit total scores than HIV– participants ($F = 21.26, p < 0.001$) (see Table 2 for group means). In terms of grit subdomains, PLWH had significantly lower consistency of interests ($F = 17.15, p < 0.001$) and perseverance of effort ($F = 8.29, p < 0.01$) than persons without HIV. The two groups did not differ in terms of ambition ($F = 0.20, p = 0.66$).

Associations Between Grit, Ambition, Premorbid IQ, Neurocognitive Functioning, and IADL Dependence in Participants With and Without HIV Infection

First we examined the relationships between WRAT (as a measure of premorbid IQ) and global neurocognitive performance. WRAT scores were not significantly related to global neurocognitive functioning among the HIV– participants ($r = 0.20, p = 0.06$), but these two variables were related in the HIV+ group such that higher WRAT scores were related to better neurocognitive functioning ($r = 0.20, p = 0.04$). Given the r -values were the same in both groups, the lack of a significant finding in the HIV– group may be a function of sample size. IADL dependence was unrelated to

Table 2 Descriptive statistics for demographic variables and test scores for HIV+ and HIV- groups

	HIV+ (N = 120)	HIV- (N = 94)	t or χ^2	df	p value
Demographic characteristics					
Age (years), M (SD)	50.54 (8.52)	51.03 (7.68)	0.44	207.81	0.659
Sex, % female	16.67	28.7	4.44	1	0.035
Race/ethnicity, % white (vs. non-white)	54.2	70.2	5.79	1	0.016
% Black	19.17	12.77	–	–	–
% Latino	18.33	14.89	–	–	–
% Other	7.50	2.13	–	–	–
Education (years), M (SD)	14.04 (2.32)	15.04 (2.31)	3.14	200.17	0.002
Grit scale variables					
Grit Scale total score, M (SD)	3.55 (0.63)	3.87 (0.42)	4.71	207.41	< 0.0001
Consistency of interests score, M (SD)	3.23 (0.84)	3.65 (0.57)	4.26	208.19	< 0.0001
Perseverance of effort score, M (SD)	3.86 (0.78)	4.12 (0.53)	2.93	208.21	0.004
Ambition Scale					
Ambition score, M (SD)	3.76 (0.80)	3.77 (0.67)	0.12	212	0.91
Neurocognitive variables					
WRAT, M (SD)	102.96 (13.73)	106.80 (13.66)	2.03	199.73	0.044
Global mean T-score, M (SD)	46.74 (7.00)	49.87 (5.99)	3.52	210.34	0.0005
Verbal mean T-score, M (SD)	49.23 (8.51)	50.59 (6.68)	1.31	211.997	0.192
Executive functioning mean T-score, M (SD)	47.80 (9.73)	52.88 (9.43)	3.85	202.37	0.0002
Speed of info processing mean T-score, M (SD)	48.88 (8.69)	52.16 (8.47)	2.78	201.90	0.006
Learning mean T-score, M (SD)	40.88 (8.99)	44.70 (9.32)	3.01	196.35	0.003
Recall mean T-score, M (SD)	41.35 (9.17)	44.21 (9.24)	2.25	198.99	0.026
Working memory mean T-score, M (SD)	48.07 (9.22)	49.44 (10.69)	0.99	184.25	0.326
Motor mean T-score, M (SD)	49.75 (10.63)	53.68 (10.47)	2.68	200.23	0.008
Everyday functioning					
IADL dependence, % dependence	18.97	1.08	21.14	1	< 0.0001
Psychiatric characteristics					
Lifetime MDD, % MDD	52.99	20.65	23.58	1	< 0.0001
Current MDD, % MDD	11.21	0.00	15.87	1	< 0.0001
Lifetime alcohol dependence, % dependence	30.51	9.78	14.13	1	0.0002
Lifetime marijuana dependence, % dependence	13.56	1.09	13.36	1	0.0003
Lifetime other substance use, % dependence	0	0	0	0	–
HIV disease characteristics					
Est. duration of HIV (years), M (SD)	17.18 (8.66)	–	–	–	–
AIDS, % AIDS	59.17	–	–	–	–
cART, % HAART	91.53	–	–	–	–
Nadir CD4 (cells/ul), M (SD)	242.26 (244.31)	–	–	–	–
Current CD4 (cells/ul), M (SD)	654.87 (324.21)	–	–	–	–
Plasma detectable, % detectable	7.48	–	–	–	–

HIV+ = HIV-infected individuals, *HIV-* = non-infected controls, *IADL* = independent Activities of Daily Living, *MDD* = Major Depressive Disorder; *HIV* = Human Immunodeficiency Virus, *AIDS* = acquired immune deficiency syndrome; *cART* = combination antiretroviral therapy

WRAT scores ($r = 0.01$, $p = 0.96$) and global neurocognitive functioning ($r = 0.14$, $p = 0.12$) in our sample of PLWH. As previously stated, only one of the HIV- participants met criteria for IADL dependence, therefore no analyses with this variable could be conducted in this group.

Next we examined the relationships between HIV status, grit/ambition, WRAT, and global neurocognitive

functioning. As shown in Table 2, the HIV- group had significantly higher WRAT and global neurocognitive functioning scores than the HIV+ group. In linear regression models, grit total score, consistency of interests, and perseverance of effort were unrelated to WRAT performance in both groups. More ambition was related to higher WRAT scores in the HIV- (Beta = 0.22; $p = 0.04$), but not the HIV+ group

Table 3 Correlations between grit total score, grit subdomains, and ambition by HIV serostatus

	Consistency of interests	Perseverance of effort	Ambition
HIV- participants (N = 94)			
Grit total score	0.78***	0.74***	0.45***
Consistency of interests	–	0.16	0.06
Perseverance of effort	–	–	0.65***
HIV+ participants (N = 120)			
Grit total score	0.79***	0.75***	0.53***
Consistency of interests	–	0.20*	0.16
Perseverance of effort	–	–	0.68***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

($p > 0.05$). A follow-up multiple regression models was conducted to examine the main effects of HIV status and ambition, as well as the interaction of HIV status x ambition, on WRAT scores (controlling for demographic variables that differed between the two groups). In this model, no main effects of HIV status or ambition was found for performance on the WRAT.

We ran similar linear regression models examining the relationships of grit and ambition on global neurocognitive functioning by group. The relationships between grit total score and consistency of interests with neurocognitive functioning were unrelated in both group. However, higher perseverance of effort (Beta: 0.27, $p < 0.01$) and more ambition (Beta: 0.28, $p < 0.01$) were related to better neurocognitive functioning in the HIV+, but not the HIV- group (p 's > 0.05). To future examine these relationships, we ran multiple regression models to examine the main effects of HIV status and perseverance of effort (model 1) and ambition (model 2), as well as the interaction of HIV status x perseverance of effort/ambition, on neurocognitive functioning (controlling for demographic variables that differed between the two groups). We found a main effect for HIV status (Beta = 0.21, $p < 0.01$), but not perseverance of effort (Beta = -0.22, $p = 0.60$) or their interaction (Beta = 0.46, $p = 0.27$), on neurocognitive functioning. For ambition, a main effect was found for HIV status (Beta = 0.25, $p < 0.001$), trend-level main effect for ambition (Beta = 0.69, $p = 0.06$), and significant interaction between HIV status and ambition (Beta = 0.88, $p = 0.02$) such that higher ambition was related to better neurocognitive functioning in the HIV+ but not the HIV- group (see Fig. 1).

Furthermore, IADL independence was related to higher total grit scores ($r = 0.32$, $p < 0.001$), higher consistency of interests ($r = 0.25$, $p < 0.01$), and higher perseverance of effort ($r = 0.26$, $p < 0.01$) among PLWH. Higher ambition ($r = 0.22$, $p = 0.02$) was also related to IADL independence.

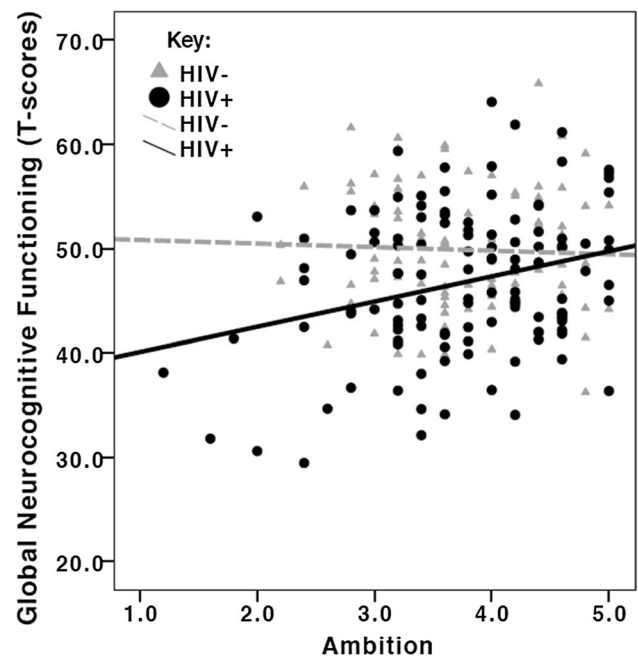


Fig. 1 Interaction between HIV serostatus and ambition with global neurocognitive functioning

Clinical Correlates of Grit and Ambition Among PLWH

We were also interested in examining the clinical correlates of grit in our sample of PLWH (correlation coefficients and p -values are presented in Table 4). First, we examined the relationships between grit and demographic characteristics. Older age was related to higher consistency of interests, and higher formal years of education were related to higher perseverance of effort. No other significant relationships between grit and demographic characteristics (sex or race/ethnicity) were observed. Additionally, there were no significant relationships between demographic characteristics and ambition.

Next, we examined the relationships between grit and ambition with HIV disease characteristics and mood. An undetectable viral load was related to higher total grit scores and higher consistency of interests. Longer estimated duration of HIV was related to higher consistency of interests. A lower current CD4 count was related to higher perseverance of effort and higher ambition, and a lower nadir CD4 count was related to higher perseverance of effort and higher ambition. Not having a history of lifetime major depression or current major depression was related to more grit (grit total score and the two subscales).

Table 4 Correlations between grit, ambition, and demographic and clinical characteristics by HIV serostatus

	Total Grit	Consistency of interests	Perseverance of effort	Ambition
HIV– participants (N = 94)				
Demographics				
Age	– 0.08	0.02	– 0.15	– 0.21*
Education	0.12	0.08	0.11	– 0.05
Sex	– 0.12	– 0.10	– 0.08	– 0.11
Race/ethnicity	– 0.20	– 0.05	– 0.27**	– 0.22*
Neurocognitive variables				
WRAT	– 0.10	– 0.05	– 0.10	– 0.22*
Global neurocognitive functioning	0.01	– 0.05	0.07	– 0.04
HIV+ participants (N = 120)				
Demographics				
Age	0.16	0.23*	0.01	– 0.17
Education	0.08	– 0.06	0.20*	0.15
Sex	– 0.10	– 0.01	– 0.15	– 0.02
Race/Ethnicity	– 0.09	– 0.05	– 0.09	– 0.17
Neurocognitive variables				
WRAT	0.02	– 0.06	0.10	– 0.05
Global neurocognitive functioning	0.17	0.00	0.27**	0.28**
IADL dependence	0.33**	0.25**	0.26**	0.22*
HIV disease characteristics				
Estimated duration of HIV	0.12	0.22*	– 0.05	– 0.08
Undetectable viral load	0.21*	0.23*	0.43	– 0.04
Current CD4 count	– 0.10	0.03	– 0.19*	– 0.19*
Nadir CD4 count	– 0.10	– 0.02	– 0.14	– 0.19*
Psychiatric characteristics				
Lifetime history of major depression	– 0.28**	– 0.23*	– 0.20*	– 0.20*
Current major depression	– 0.28**	– 0.22*	– 0.21*	– 0.36**
Lifetime alcohol dependence	– 0.08	– 0.11	– 0.02	– 0.09
Lifetime marijuana dependence	– 0.03	– 0.09	0.04	– 0.02
Lifetime other substance use dependence	– 0.11	– 0.07	– 0.11	– 0.08

* $p < 0.05$; ** $p < 0.01$

Multiple Regression Analyses

We were interested in determining whether there were main effects and an interaction between grit, ambition and pre-morbid IQ (i.e., WRAT scores) on predicting neurocognitive functioning among PLWH. As neither grit nor WRAT scores were related to neurocognitive functioning among the HIV– participants, these analyses were only performed in PLWH. All demographic, psychiatric, substance use, and HIV disease characteristics presented in Table 2 were considered as possible covariates via a univariable screening process, and those that were significant at $p < 0.05$ were included in final multiple linear regression models. As seen in Table 5, higher perseverance of effort and higher ambition were related to better global neurocognitive functioning independent of covariates, and no interactions were observed in any of the models.

Lastly, we ran separate logistic regression models predicting IADL status (dependence versus independence) from grit and ambition, controlling for the variables related to grit and ambition (Table 6). In four independent logistic regression models examining total grit score, grit subscales, and ambition, higher total grit scores, higher consistency of interest, and higher perseverance of effort remained significant predictors of IADL independence, though ambition was not related to IADL status when controlling for covariates.

Discussion

Consistent with our first study hypothesis, we found lower grit scores in PLWH compared to persons living without HIV. Secondly, we found that among PLWH, higher perseverance of effort was related to better neurocognitive

Table 5 Grit, ambition, premorbid IQ, and neurocognition functioning among PLWH: regression results

	B	SE	Beta	p value	95% lower	95% upper
Grit subdomain: perseverance of effort						
Perseverance of effort	2.03	0.87	0.23	0.02	0.31	3.76
WRAT	0.13	0.06	0.25	0.05	0.00	0.26
Perseverance of effort × WRAT interaction	-0.08	0.06	0.25	0.22	-0.20	0.05
Education	-0.48	0.36	-0.16	0.19	-1.20	0.24
Current CD4 count	-0.00	0.00	-0.16	0.09	-0.01	0.01
Lifetime MDD	0.92	1.43	0.07	0.52	-1.92	3.76
Current MDD	-0.98	2.29	-0.04	0.67	-5.52	3.56
Ambition						
Ambition	2.63	0.90	0.31	0.004	0.84	4.41
WRAT	0.17	0.06	0.34	0.007	0.05	0.30
Ambition × WRAT interaction	-0.05	0.05	-0.93	0.33	-0.16	0.05
Education	-0.55	0.36	-0.18	0.13	-1.27	0.17
Nadir CD4 count	0.00	0.00	0.05	0.69	-1.01	0.01
Current CD4 count	-0.00	0.00	-0.19	0.09	-0.01	0.00
Lifetime MDD	1.26	1.44	0.09	0.38	-1.59	4.11
Current MDD	-0.19	2.35	-0.01	0.94	-4.84	4.47

Perseverance of effort, ambition, and WRAT scores were configured as z-scores and centered around zero
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Table 6 Grit, ambition, premorbid IQ, and IADL independence versus dependence among PLWH: logistic regression results

	B	SE	Wald	p-value	Exp(B)	95% lower	95% upper
Model 1: Grit total score							
Grit total score	2.34	0.74	10.14	0.001	0.40	2.46	43.95
Education	-0.14	0.14	1.07	0.30	0.87	0.67	1.13
Detectable viral load	1.40	1.27	1.21	0.27	4.07	0.34	49.30
Lifetime MDD	-1.06	0.79	1.80	0.18	0.35	0.07	1.63
Current MDD	1.59	0.88	3.26	0.07	4.91	0.87	27.59
Model 2: Grit subdomain: consistency of interests							
Consistency of interests	0.93	0.43	4.72	0.03	2.54	1.10	5.90
Education	-0.05	0.13	0.17	0.68	0.95	0.74	1.22
Estimated duration of HIV	0.01	0.03	0.18	0.67	1.01	0.95	1.08
Detectable viral load	1.11	1.27	0.76	0.38	3.02	0.25	36.09
Lifetime MDD	-0.35	0.68	0.26	0.61	0.71	0.19	2.70
Current MDD	1.38	0.81	2.88	0.09	3.97	0.81	19.57
Model 3: Grit subdomain: perseverance of effort							
Perseverance of effort	0.82	0.37	5.03	0.03	2.28	1.11	4.69
Education	-0.11	0.12	0.86	0.36	0.89	0.71	1.13
Current CD4 count	-0.00	0.00	0.47	0.49	1.00	1.00	1.00
Lifetime MDD	-0.50	0.62	0.64	0.43	0.61	0.18	2.06
Current MDD	0.97	0.81	1.45	0.23	2.65	0.54	12.88
Model 4: Ambition							
Ambition	0.59	0.35	2.78	0.10	1.80	0.90	3.58
Education	-0.07	0.12	0.34	0.56	0.94	0.75	1.17
Nadir CD4 count	0.00	0.00	0.57	0.45	1.00	1.00	1.00
Current CD4 count	-0.00	0.00	1.51	0.55	1.00	1.00	1.00
Lifetime MDD	-0.36	0.60	0.36	0.55	0.70	0.22	2.26
Current MDD	0.78	0.81	0.93	0.34	2.19	0.45	10.73

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performance, while among adults without HIV infection, grit was unrelated to neurocognition. Higher grit (perseverance of effort and consistency of interest) was also associated with IADL independence among PLWH. Our study conceptualized grit as a potential protective factor for cognitive function in PLWH. As a psychological reserve factor, grit was unrelated to the WRAT, which is traditionally a proxy metric of cognitive reserve/premorbid IQ. In our sample of PLWH, WRAT was related to better neurocognitive performance, but was not associated with IADL independence. Thus, grit as a psychological, non-cognitive protective factor was related to an important outcome of everyday functioning among PLWH that a cognitive reserve measure did not capture.

Surprisingly, WRAT scores were unrelated to neurocognitive performance in our sample of adults without HIV infection. Previous studies have found single word reading tools, such as the WRAT or National Adult Reading Test 4 [36], assess previous knowledge and education with low demands on other cognitive abilities in non-patient populations [37, 38], so there may be unique characteristics of our HIV- participants that cause them to differ from national normative comparison samples. In addition, WRAT scores were strongly correlated with education, and our neuropsychological scores were adjusted for education, perhaps accounting for this finding. Our third hypothesis posed that there would be an interaction between grit and premorbid IQ on global cognition among PLWH. No significant interactions were identified, suggesting that the association of grit and its components with global cognition did not vary by level of premorbid cognitive ability. It is important to distinguish current grit findings from other seemingly-related positive psychosocial factors such as resilience. While resilience has been used by some as a synonym for grit, they have been identified as unique constructs. The grit scale attempts to capture strength of character (sustaining effort via consistency of interests and perseverance of effort), while measures of resilience tend to capture adaptive coping (“bouncing back”) in dealing with life’s challenges.

We also examined the role of ambition in relation to neurocognitive and everyday functioning. Contrary to grit scores, ambition scores did not differ between the HIV+ and HIV- groups. However, a significant interaction was found such that higher ambition was related to better neurocognitive performance among PLWH but not among persons without HIV. While the ambition scale has yet to be validated, large effect sizes were observed between ambition with grit total scores and perseverance of effort in both groups, suggesting ambition may be capturing some overlapping characteristics of grit. Indeed, both concepts can be conceptualized as trait-like factors related to the accomplishment of effort, persistence and tenacity rather than talent or ability. Ambition is often perceived as a negative trait,

in that by definition to be ambitious is for the purpose of distinguishing oneself from others, whereas grit is thought to be persevering through adversity and failure for the sake of achievement itself (without external recognition). However, both constructs include desire, motivation, and determination to achieve, which may be important components of cognitive health. Future studies are needed to validate the ambition scale and explore whether it is perhaps a third component of grit.

Expanding the model of cognitive reserve to include psychological reserve factors may help to capture important constructs for successful adult neurocognitive and everyday functioning that may be missing from its current paradigm [18]. Prior studies on the role of cognitive reserve in neurocognitive functioning and impairment in PLWH have conceptualized cognitive reserve as being comprised of years of education, vocabulary knowledge/verbal IQ, leisure time, and/or occupational achievement [11, 39–41]. These traditional measures of cognitive reserve appear to account for mean differences in cognitive functioning in older adults but do not predict differential rates of cognitive decline [42]. The contribution of psychological reserve factors, such as grit, self-efficacy, and conscientiousness, as independent modifiers of risk for cognitive decline in older have been examined in several cohorts of older adults [19, 43, 44]. In a longitudinal study of older adults without HIV infection, grit, conceptualized in terms of high school class rank controlling for IQ, predicted better cognitive performance (immediate and delayed recall) and slower rates of cognitive decline in later life [19]. The study utilized a non-validated assessment of grit, however, and its conceptualization as high school class rank may be too closely tied to academic achievement, a typical proxy measure of cognitive reserve.

Our study extends these findings by employing a validated self-assessment of grit, which was unrelated to premorbid cognitive function, and furthermore, examined grit as a potentially protective psychological reserve construct in both neurocognition and everyday function in PLWH. As such, this study incorporates both cognitive and psychological reserve components in an attempt to more fully capture some of the large individual differences in cognitive and everyday functioning found in PLWH.

In our sample of PLWH, both premorbid IQ and the nontraditional, non-cognitive reserve factors of grit and ambition was related to cognitive performance. Grit was related to IADL dependence among PLWH, whereas our measure of premorbid IQ was not. Previous studies have also observed this mismatch between cognitive performance and daily functioning [45–47], which may be due to other factors, serving as barriers (e.g., depression) and facilitators (e.g., grit) to daily functioning in PLWH. Grit and ambition were unrelated to neurocognition in the HIV- group. Although these findings are preliminary and

utilize cross-sectional data, they suggest that grit may be particularly salient for cognitive and functional outcomes in PLWH. Grit may serve as a protective factor in cognitive aging in that it reflects determination, endurance, and drive, which may be especially relevant for PLWH who commonly face multiple adverse experiences related to HIV stigma [48], physical and sexual abuse [49, 50], and have higher rates of major depressive disorder and PTSD compared to their HIV— counterparts [51, 52]. However, we note that our findings showed that higher grit was associated with not having a lifetime history or current major depressive episode. We hypothesize that other past adverse experiences, which are common in PLWH, and unmeasured in this study, may relate to higher current grit scores. Grit and its components may facilitate active adaptation to challenges and adverse situations in PLWH that contribute to maintained cognition and independent daily functioning. In this model, grit can also be conceptualized as a malleable asset that is impacted by life experiences, and in turn, influences how individuals cope with age-related cognitive changes. This is consistent with the theoretical model of cognitive reserve, which is also dynamic, adaptable, and acquired overtime through cognitively demanding environments [13]. Cognitive factors and the non-cognitive components of grit (consistency of interests and perseverance of effort) may act in a cumulative or bidirectional manner to influence cognitive and everyday functioning abilities in PLWH; however, this theory is speculative at this time. Future longitudinal studies are needed to determine if grit does serve as a protective factor for cognition and everyday functioning.

Our study has several strengths. We had a large sample of persons living with and without HIV infection with comprehensive neuropsychological, psychiatric, medical, functional, substance use, and HIV disease characteristic data. We used a validated self-assessment of grit and the WRAT-4 to assess premorbid intellectual ability, employing both traditional and nontraditional proxies of cognitive reserve in our analyses. To the best of our knowledge, this was the first study to examine the relationship between grit and IADL independence versus dependence.

There are also several limitations to this study. Our observational and cross-sectional study design did not allow for the examination of the direction of influence among our variables of interest, limiting causal inferences. It is also possible, given our cross-sectional design, that grit does not precede and predict higher cognitive performance and everyday functioning, but instead captures perspectives on endurance and aspiration that have resulted from particular life experiences. Another limitation is that our grit predictor and one of our main outcomes, functional dependence, are both self-report measures, and thus their significant association may be partially related to a positive tendency in reporting. These data represent baseline data from a longitudinal

study; in future work, we will be able to begin to examine whether grit is a stable, predictive, and protective factor for better neurocognitive and everyday functioning. We will also be able to examine the longitudinal role of ambition on cognitive outcomes. Individuals who experienced more functional difficulties, cognitive declines, or other adverse situations may be less likely to strongly endorse items tapping consistency of interests, perseverance of effort, and grit. Longitudinal cohorts will be essential in clarifying the relationships between grit, aging, HIV, cognitive abilities, and the potential mechanisms, which underlie these links in older adults. Finally, our sample is not demographically representative of the national HIV+ population in the United States (U.S.). Nationally, HIV disproportionately affects people of color, in particular African-Americans and Latinos who make up 62% of PLWH in the U.S [53]. Our sample of PLWH is 16.8% Latino and 16.4% African-American, and primarily White (61.2%).

In conclusion, this study provides preliminary support for grit as potential psychological reserve contributor, above and beyond the effects of cognitive reserve, to better cognitive and everyday functional outcomes in PLWH. Future work should examine how grit interacts with other positive psychological and cognitive factors, as well as environmental experiences and immune function, which may cumulatively contribute to compensatory reserve mechanisms. Research on grit and other non-cognitive, potentially protective factors such as self-efficacy, resilience, and motivation may eventually inform the development of multipronged interventions aimed at improving cognitive well-being and quality of life among persons living and aging with HIV.

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Compliance and Ethical Standards

Conflict of interest None of the authors have conflicts of interest.

Ethical Approval This research involved human subjects. The study was approved by the UCSD Institutional Review Board, and all participants provided written, informed consent.

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