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Driving habits, cognition, and health-related quality of life in middle-aged and older adults with HIV

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ABSTRACT

Cognitive impairment is known to increase with aging in people living with HIV (PLWH). Impairment in cognitive domains required for safe driving may put PLWH at risk for poor driving outcomes, decreased mobility, and health-related quality of life (HRQoL). This study described the driving behaviors of middle-aged and older PLWH and examined correlations between driving behaviors and cognitive functioning (Aim 1), and driving behaviors and HRQoL domains (Aim 2). A sample of 260 PLWH ages 40 and older completed a comprehensive assessment including a battery of cognitive tests, an HRQoL measure, and a measure of self-reported driving habits. Associations between driving habits, cognitive function, and HRQoL domains were examined. While 212 (81.54%) participants reported currently driving, only 166 (63.85%) possessed a driver's license. Several significant correlations emerged between driving habits and both cognitive and HRQoL variables, with a general pattern suggesting that current greater driving exposure was associated with better cognitive functioning and HRQoL. Given consistent associations that emerged between the social functioning HRQoL domain and several driving habits, multivariable regression was conducted to examine the unique association between an index of greater driving exposure (i.e., days driven per week) and social functioning, adjusting for potential confounders (race, income, education, depression, and global cognition). Results showed that more days driven per week was a significant, independent correlate of higher social functioning. Understanding the factors underlying driving behaviors in PLWH may contribute to interventions to promote better mobility and improved access to care.

KEYWORDS
Aging; AIDS; attention/perception; HIV

In 2018 in the United States, 51% of people living with HIV (PLWH) were 50 and older, due mostly to effective anti-retroviral therapies that have restored the lifespan of PLWH to nearly normal (Centers for Disease Control and Prevention (CDC), 2020). In fact, this number is expected to increase to 70% by 2030 (Wing, 2017). Despite improved longevity, PLWH continues to suffer from cognitive impairments (Heaton et al., 2011; Vance et al., 2013) across a variety of cognitive domains such as psychomotor speed, executive functioning, speed of processing, memory, and learning (Heaton et al., 2015; Vance et al., 2013; Woods et al., 2009). Cognitive impairments associated with HIV may further be exacerbated by aging and age-related comorbidities (Vance et al., 2014). Cognitive impairments can interfere with complex instrumental activities of daily living (IADL) such as financial management and medication adherence; however, one activity that may be uniquely impacted is driving (Marcotte et al., 2006; Vance et al., 2014).

Driving is the IADL with the greatest potential for harm to others as well as to the driver. In addition, driving is a cognitively demanding task, calling upon numerous domains including spatial navigation and memory skills, attentional resources, multitasking abilities, executive functioning, and psychomotor skills (Hirth et al., 2007). Affirming the cognitive components of driving, a number of studies examining on-road, simulated, and self-reported driving performance have suggested associations between cognitive impairments and driving ability in a variety of neurocognitive diseases (Rashid et al., 2020; Uc et al., 2017; Vance et al., 2014).

In the context of HIV, Marcotte et al. (2004) examined on-road driving, simulated driving, Useful Field of View (UFOV®) performance (a computerized test of visual speed and attention associated with higher crash risk and driving performance), and cognitive performance in other domains in a sample of 60 middle-aged licensed drivers (M_{age} = 41.94 years; $n = 40$ HIV+, $n = 20$ HIV-). Drivers with HIV and cognitive impairment performed worse on all driving measures than drivers without HIV and drivers without HIV without cognitive impairment. Further, simulated driving and cognitive performance independently predicted on-road driving performance (Marcotte et al., 2004). In another

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study of 63 licensed drivers (M_{age} = 42.25 years; $n = 42$ HIV+, $n = 21$ HIV−), Marcotte et al. (2006) found that drivers with HIV had poorer UFOV® performance than those without HIV and this impairment was associated with a greater number of self-reported crashes in the previous year. These two targeted studies suggest: (1) cognition is a valuable predictor of on-road crashes in PLWH, and (2) PLWH with cognitive impairments may experience worse driving outcomes than control groups (with or without HIV) without cognitive impairments (Vance et al., 2014).

Building on this, other studies have investigated cognitive functioning and simulated driving performance in older samples of PLWH (Foley et al., 2013; Thames et al., 2013; Vance et al., 2014). Vance et al. (2014) investigated cognitive functioning and simulated driving performance in 26 middle-aged and older PLWH (M_{age} = 51.23 years). Affirming Marcotte et al.'s findings (2006), poorer UFOV® performance along with older age was related to poorer simulated driving performance (i.e., average gross and divided attention reaction times). Mixed results were found for associations between indices of driving exposure and cognitive performance, such that better performance on a processing speed task (i.e., Trails A) was associated with more days driven per week, while poorer UFOV® performance was associated with more miles driven during the week. Foley et al. (2013) found that older (ages 50–79) PLWH were slower (i.e., longer total completion time) and less efficient (e.g., becoming lost and making more incorrect turns) in navigating a simulated driving navigation task compared to younger (ages 18–39) PLWH. Additionally, visuospatial abilities and attention independently predicted task completion time and efficiency in older PLWH (Foley et al., 2013). Thames et al. (2013) longitudinally assessed the relationship between cognitive impairments and simulated city-country driving performance in 101 PLWH (M_{age} = 49.79), finding that baseline cognitive impairments predicted 1-year follow-up cognitive impairments and slower baseline speed of processing was related to increased simulated driving errors (e.g., crashes, pedestrian hits, off-road crashes, illegal turns, speeding tickets) at follow-up.

Driving performance and habits may affect the quality of life in PLWH, though very little work has examined this topic. Previous research in non-HIV samples shows a bidirectional association between driving habits such as driving cessation and driving avoidance (i.e., avoiding risky driving situations) and quality of life or health status (Anstey et al., 2006; Edwards et al., 2008; Jette & Branch, 1992). This suggests that declining health not only significantly alters driving habits, but such changes in driving habits might also alter both perceived and objective health indicators. Most recently, in a cohort of older adults ages 85 and older in Germany, Hajek et al. (2020) found evidence of a cross-sectional association between health-related quality of life (HRQoL) and driving status, such that being a current driver was associated with independence in self-care, usual activities, and mobility. Understanding the association between health status and driving habits is of great importance to middle-aged and older PLWH as described in a qualitative study by Kempf et al. (2010), which showed that access to transportation was a major factor in women with HIV's ability to access health care in the Deep South, a regional and cultural area of the United States (primarily Louisiana, Mississippi, Alabama, Georgia, South Carolina) often characterized with a history of racial oppression and health disparities. Still lacking from the literature is a detailed description of driving habits and their association with HRQoL in middle-aged and older PLWH in the Deep South, an area burdened by the current HIV/AIDS epidemic and where a larger proportion of individuals are African American of low SES and live in rural, car-dependent areas (Reif et al., 2017). For example, in a study of 260 community-dwelling older Australian adults (75–85 years), the ability to drive and resulting greater life space was associated with better mental health and less social isolation (using the SF36 HRQoL questionnaire; Byles et al., 2015). While the association between cognitive functioning and driving outcomes have been demonstrated in PLWH, little is known about the association of driving habits with HRQoL in older PLWH, who are at risk for poorer cognitive function, poorer driving performance (and potentially less driving exposure), as well as poorer HRQoL (Monteiro et al., 2016).

This review of the literature suggests that driving habits and their correlates among older PLWH remain largely unexplored. Yet, given the relationship that mobility, especially driving, has with health and quality of life in older adults (Hajek et al., 2020), this area represents a crucial topic for study in older PLWH, especially for those living in the Deep South who are more likely to be African American and of low SES. Thus, this correlational study included two aims. Aim 1 was to describe the driving habits of a sample of middle-aged and older PLWH and examine demographic and clinical correlates of driving habits, including cognitive functioning (global and domain-specific). Aim 2 was to first explore associations between driving habits and HRQoL domains, followed up with adjusted analyses examining the association between driving exposure (i.e., days driven per week) and HRQoL domain(s) which demonstrated specificity with driving habits.

Methods

Design overview

In this cross-sectional study, baseline data were obtained from a larger longitudinal clinical trial investigating the effect of a computerized cognitive training protocol on cognitive and everyday functioning including driving in 260 middle-aged and older (40+) PLWH (Vance et al., 2017). At the baseline assessment, participants were administered a comprehensive battery of cognitive performance tests along with psychosocial and health measures and a driving habits questionnaire.

Participant characteristics

Participants were recruited with flyers, brochures, and other recruitment materials placed in a university HIV/AIDS clinic

Table 1. Sample characteristics ($N = 260$).

Variable	Frequency (%)	*M* (SD)	Range
Age (years)		51.15 (6.76)	40 – 73
Race/Ethnicity			
Nonwhite	215 (82.69)		
White	45 (17.31)		
Gender			
Women	93 (35.77)		
Men	167 (64.23)		
Education (years)		12.53 (2.24)	7 – 20
Annual Household Income (≤20K)	205 (78.85)		
HIV Clinical Values[a]			
Nadir CD4+ lymphocyte count		268.83 (273.89)	1 – 1,138
Current CD4+ lymphocyte count		656.95 (375.04)	10 – 1,839
Current viral load		5,274.52 (29,545.55)	19 – 339,810
CES-D score		17.93 (11.02)	0 – 49
Cognitive domains			
Speed of processing		47.43 (8.20)	25.00 – 69.33
Working memory/attention		44.90 (9.02)	19.00 – 73.00
Learning		42.44 (7.56)	21.50 – 66.50
Memory		43.21 (7.94)	16.50 – 65.50
Verbal fluency		45.90 (7.82)	26.00 – 72.33
Executive function		46.12 (8.95)	20.00 – 72.00
Motor function		39.43 (8.92)	9.00 – 64.00
Global cognitive score		44.54 (6.02)	28.13 – 61.19
Cognitive impairment (impaired)	151 (58.01)		

CES-D = Center for Epidemiological Studies Depression Scale; *M* = mean, SD = standard deviation; [a]Clinic data were available for 236 for nadir CD4, 184 for current CD4, and 213 for viral load.

in an urban area in the Deep South. These materials directed participants to call the research office if they were interested in participating in a cognitive training study, at which point a telephone screening was used to discern eligibility. It is possible that those who called were more concerned about their cognition; thus, this sample may have been more cognitively vulnerable. Participants were eligible if they were 40 or older, diagnosed with HIV for a year or more, and English speaking. Significant neuro medical comorbidities (i.e., multiple sclerosis, schizophrenia, bipolar disorder, Alzheimer's disease) were exclusionary factors, as well as any other conditions (e.g., legally deaf or blind, history of brain trauma, homelessness) that could impact cognitive assessment and training (Vance et al., 2013). Participants provided written consent using a form approved by the university IRB.

Measures

Demographic information

Participants completed a questionnaire which collected demographic information such as age, race (nonwhite = 0; white = 1), sex (female = 0; male = 1), yearly household income (measured in $10,000 increments, ranging from 0 to above 100,000 [USD]), years of education (ranging from one to 20 years).

HIV characteristics

The University HIV/AIDS clinic where recruitment occurred provided health information related to participants' HIV status, including current viral load, current CD4+ lymphocyte count, and nadir CD4+ lymphocyte count.

Depression

Depressive symptoms were captured using the Center for Epidemiologic Studies Depression Scale-Revised (Radloff, 1977) with scores ranging from 0–60; a score of 16 or higher indicates significant depressive symptomology.

Cognitive functioning

Raw scores from each cognitive measure in the battery were converted to demographically corrected *T* scores that accounted for age, gender, education, and race when available and were then used to calculate domain-specific and global *T* scores, with higher scores indicating better performance (Heaton et al., 2010). A cognitive classification variable was also calculated to identify participants with neurocognitive impairment (NCI) using the published clinical rating approach. Participants with global clinical ratings of 5 or greater (indicating impairment in two or more cognitive domains) were classified as impaired (Blackstone et al., 2012).

The cognitive measures assessed 7 domains of cognitive functioning. Speed of processing was assessed using the Trail Making Test Part A (Lezak et al., 1995; Reitan, 1958, 1979), WAIS-III Digit Symbol (Wilde & Strauss, 2002), and WAIS-III Symbol Search (Lezak et al., 1995). Attention/working memory was assessed by the PASAT-2000 (Tombaugh, 2006) and WAIS-III Letter Number Sequencing (Lezak et al., 1995; Wilde & Strauss, 2002). Learning was assessed by the Brief Visuospatial Memory Test-Revised (BVMT-R) Trials 1-3 (Kane & Yochim, 2014) and Hopkins Verbal Learning Test-Revised (HVLT-R) Trials 1-3 (Woods et al., 2005; Woods et al., 2005). Memory was assessed by the BVMT-R Delay (Kane & Yochim, 2014) and HVLT-R Delay (Woods et al., 2005; Woods et al., 2005). Verbal

Table 2. Self-reported driving habits ($N = 260$).

Variable	Frequency (%)	M (SD)	Range
Possess valid driver's license[d]	166 (63.85)		
Currently drive[d]	212 (81.54)		
Days driven (per week)[e,d]		4.71 (2.41)	0–7
Miles driven per past year[f]		9,635.71 (15,055.03)	0–185,764
Driving experience[a,d]		4.68 (0.79)	1–5
Driving quality[b,d]		4.33 (0.76)	1–5
≥1 Collision (past 5 years)[c]	42 (19.81)		
≥1 Times pulled over (past 3 years)	71 (33.49)		
Times pulled over (past 3 years)		0.73 (1.65)	0–12
≥1 Tickets received (past 3 years)[g]	48 (23.08)		
Tickets received (past 3 years)[g]		0.44 (1.09)	0–8

M = mean, SD = standard deviation; [a]Driving Experience (1 = not very experienced; 5 = very experienced). [b]Driving quality (1 = poor; 5 = excellent). [c]The range for collisions was 0 to 1. [d]Includes responses for all 260 participants; all other driving items were reported for current drivers only ($N = 212$). [e]Data were available for 258 participants. [f]Data were available for 207 participants. [g]Data were available for 208 participants.

Fluency was assessed by the Controlled Oral Word Association Test (COWAT) – FAS (Lezak et al., 1995) and Animal Fluency (Woods et al., 2005). Executive functioning was assessed by the Wisconsin Card Sorting Test (Lineweaver et al., 1999) and Trails Making Test Part B (Lezak et al., 1995; Reitan, 1958, 1979). Motor function was assessed by the Grooved Pegboard (dominant and non-dominant) tasks (Matthews & Klove, 1964).

Driving Habits Questionnaire (DHQ)

The Driving Habits Questionnaire (DHQ) was designed to collect self-reported driving information (Owsley et al., 1999). The current study administered a condensed version of the DHQ, assessing current driving, driving exposure, and self-reported crashes and citations. Current driving items asked whether participants currently drove [yes (1) or no (0)], whether they possessed valid driving licensure [yes (1) or no (0)], and how they would rate their current driving quality (1 = poor; 5 = excellent) and driving experience (1 = not very experienced; 5 = very experienced). Driving exposure items inquired about the number of days driven per week ($1-7$) and miles driven per year. Self-reported crashes and citations gathered information about the number of motor vehicle crash in the past 5 years, as well as the number of times pulled over and the number of tickets received (other than parking tickets) in the past 3 years.

Medical Outcomes Survey-HIV (MOS-HIV)

The Medical Outcomes Survey-HIV (MOS-HIV) was adapted from a previous version of the Medical Outcomes Survey SF36 HRQoL Questionnaire to capture HRQoL data in participants with HIV (Wu et al., 1997; Wu et al., 1991). This widely used and well-validated self-report questionnaire consists of 35-items across 11 domains: general health perceptions, physical functioning, role functioning, pain, social functioning, mental health, energy/fatigue, health distress, cognitive functioning, quality of life, and health transition (Cooper et al., 2017). The present study analyzed each of these domains. Values for domains are converted to a 100-point scale with higher values indicating better HRQoL.

Data analysis

Descriptive statistics (means, standard deviations [*SD*s], ranges) were calculated for all study variables (Tables 1 and 2). For Aims 1 and 2, correlations were conducted between demographic and clinical variables (including cognitive functioning) and DHQ variables, as well as DHQ and HRQoL variables. Given that the driving variables were not normally distributed and some were binary, Spearman's correlation analyses were used (Table 3). Note, associations between DHQ variables and other study variables only included participants who were current drivers ($n = 212$) for miles driven per past year, crashes per past 5 years, and times pulled over and tickets per past 3 years as these variables values were only relevant for current drivers, while all participants ($N = 260$) were included for current driving status, license status, days driven per week, driving quality, and driving experience. For Aim 2, multivariable linear regressions were conducted for each HRQoL domain that showed significant univariate associations with driving exposure (i.e., days driven per week), adjusting for any correlates that were significantly ($p < 0.05$) associated with either day driven per week or the HRQoL domain (Table 4).

Results

Sample characteristics

Participants had a mean age of 51.15 years (SD = 6.76, range = 40–73), and were mostly male (64.23%) and non-white (82.69%; see Table 1). The mean education level was 12.53 years (SD = 2.24, range = 7–20) and most of the sample (78.85%) had ≤$20,000 in annual household income. The mean nadir CD4+ lymphocyte count was 268.83 cells/μL, with 122 (51.26%) below 200 cells/μL, often indicative of an AIDS diagnosis. The mean current CD4+ lymphocyte count was 656.95 cells/μL and the mean current viral load was 5,274.52 copies/μL; only 19 participants (10.27%) had a CD4+ lymphocyte count below 200 cells/μL indicative of AIDS, and most (66.36%) had an undetectable viral load. This viral suppression rate is similar to the national average of 65% in 41 states and the District of Columbia according to a CDC 2018 report (Phillips, 2021). In our university HIV/AIDS clinic, 71% have an undetectable viral load; our

Table 3. Spearman's Rho Correlations for Associations between Driving Habits and Cognitive Functioning and Health-Related Quality of Life Domains.

Variable	1	2	3	4	5	6	7	8	9
1 Current driver[b]	1.00	.41****	.56****	.54****	.20***	.30****	.16†	.15*	.10
2 Currently Licensed[b]		1.00	.50****	.51****	.29****	.31****	.17†	.15*	.11
3 Days per week[b]			1.00	.82****	.27****	.23***	.23****	.28****	.24****
4 Miles per year				1.00	.23***	.26****	.11	.21**	.17**
5 Driving experience[b]					1.00	.53****	.11	.12*	.12
6 Driving quality[b]						1.00	−.07	.12	.12
7 ≥1 Collision							1.00	.19**	.16**
8 Times pulled over								1.00	.73****
9 Times ticketed									1.00
Speed of processing	.10	.26****	.15*	.25**	.20***	.25****	−.05	.09	.05
Work mem/attention	.05	.12	.01	.22**	.17**	.10	.01	.10	.05
Learning	.05	.12	.03	.09	.12*	.09	−.06	.003	.03
Memory	−.004	.08	.01	.11	.13*	.04	−.01	−.03	−.01
Verbal fluency	.05	.07	.01	.02	.14*	.10	−.03	.05	.03
Executive function	−.01	.03	.09	.23***	.14*	.14*	.08	.03	.06
Motor function	.02	.08	.13*	.17**	.13*	.18**	.02	−.05	−.10
Global cognitive function	.06	.17**	.09	.22***	.20***	.17**	.01	.05	.04
Cognitive impairment[a]	.04	−.07	−.03	−.19**	−.10	−.02	−.07	−.01	.06
General health perception	.01	.04	.12	.09	.05	.17**	.00	.11	.09
Physical functioning	.10	.05	.09	-.02	.10	.20***	−.13	.08	.04
Social functioning	.17**	.16**	.17**	.09	.07	.19**	-.06	.14*	.10
Role functioning	−.02	.04	.10	.11	.01	.06	−.07	.19**	.09
Cognitive functioning	.15*	.06	.09	−.03	.09	.17**	.03	.02	.04
Pain	−.07	.01	−.01	.03	−.03	.10	−.05	.13	.09
Mental health	−.06	−.05	.04	.05	.11	.12	.12	.09	.00
Energy/fatigue	−.05	−.09	−.09	−.14*	−.01	.03	−.02	.05	−.00
Health distress	.05	.03	.06	.04	.18**	.18**	.02	.08	.05
Quality of life	−.02	.06	−.03	−.09	−.03	−.00	.12	−.01	−.06
Health transition	−.09	−.13*	−.11	−.13	−.05	−.01	−.03	−.12	−.11

*$p \le 0.05$; **$p \le 0.01$; ***$p \le 0.001$; ****$p \le 0.0001$; [a]0 = normal, 1 = impaired; [b]Includes responses for all 260 participants; all other driving variables were reported for current drivers only ($N = 212$).

Table 4. Multiple regression estimates for the Social Functioning HRQoL Domain.

	Dependent variable: social functioning		
Variables	B (SE)	Lower 95% CI	Upper 95% CI
Intercept	49.99 (12.55)	25.28	74.70
Days driven per week	1.02 (0.51)	0.02	2.02
Global T score	1.02 (0.23)	0.57	1.46
Race (nonwhite)	−4.62 (1.87)	−8.31	−0.94
Income	−0.77 (0.93)	−2.60	1.06
Education	−0.11 (0.67)	−1.43	1.20
CES-D*	−0.99 (0.13)	−1.24	−0.74

CES-D: Center for Epidemiological Studies-Depression Scale.
95% CIs are statistically significant at $p < 0.05$ if they do not contain 0.

sample is similar to this rate as well. Depressive symptomology scores yielded from the CES-D showed that 133 (50.96%) participants had a score indicative of clinically meaningful depressive symptomology. Overall, 151 (58.01%) participants met the clinical criteria for neurocognitive impairment.

Aim 1: self-reported driving habits and cognitive correlates

We first examined descriptive statistics for driving habits, participants from the total sample ($N = 260$; see Table 2) reported driving an average of 4.71 (SD = 2.41) days (out of 7) per week. Participants self-reported high levels of driving experience (4.68 [SD = 0.79]) and rated themselves as very good or excellent quality drivers (4.33 [SD = 0.76]), based on a 5-point Likert scale. In the full sample, 166 (63.85%) possessed a current valid driver's license, while 212 (81.54%) reported currently driving. Of the 212 participants that reported currently driving, 155 (73.11%) participants had valid driver's licenses. Among those who reported currently driving regardless of license status ($n = 212$), participants reported driving an average of 9,635.71 (SD = 15,055.03) miles per year. Among drivers, only 42 (19.81%) participants reported involvement in one or more crashes within the past 5 years and 71 (33.49%) drivers reported being pulled over at least once in the past 3 years. Only 48 (23.08%) of the 208 with valid data for this item reported being ticketed within the past 3 years.

We also examined intercorrelations among driving variables (Table 3). Current drivers were more likely to be licensed, drove more days per week, more miles per year, reported greater driving experience and better driving quality had more collisions and more instances of being pulled over. Similar results were found for licensed drivers. Greater days per week and miles per year were associated with greater self-reported driving experience and better driving quality. As expected, greater driving exposure (either greater days per week or miles per year) was associated with greater likelihood of having a collision, being pulled over, and being ticketed. Similarly, as expected, being pulled over more was related to being ticketed more.

We then examined demographic and clinical correlates of driving habits and found that White race was associated with a greater likelihood of being a current driver (rho = 0.14, $p < 0.05$), greater likelihood to possess licensure (rho = 0.18, $p < 0.01$), more days driven per week (rho = 0.18, $p < 0.01$), more miles driven per year (rho = 0.22, $p < 0.01$), and greater self-reported driving experience (rho = 0.15, $p < 0.01$). Older age was positively associated with licensure (rho = 0.16, $p < 0.01$) and negatively correlated with the number of tickets (rho = −0.17, $p < 0.05$). More years of education was associated with a greater likelihood of being a current driver (rho = 0.27, $p < 0.01$), a greater likelihood of being a licensed driver (rho = 0.42, $p < 0.01$), more days driven per week (rho = 0.29, $p < 0.01$), more miles driven in the past year (rho = 0.29 $p < 0.01$), greater self-reported driving experience (rho = 0.18, $p < 0.01$), better self-reported driving quality (rho = 0.20, $p < 0.01$), and reporting more occasions of being pulled over by the police in the past 3 years ($r = 0.20$, $p < 0.01$). Higher-income was associated with being a current driver (rho = 0.15, $p < 0.01$), possessing a valid license (rho = 0.27, $p < 0.01$), more days driven per week (rho = 0.33, $p < 0.01$), more miles driven per year (rho = 0.41, $p < 0.01$), better self-reported driving quality (rho = 0.15, $p < 0.05$), and greater likelihood to report a collision (rho = 0.21, $p < 0.01$). Higher nadir CD4+ lymphocyte counts were negatively associated with being a currently licensed driver (rho = −0.13, $p < 0.05$) while higher current CD4+ lymphocyte counts were associated with were less likelihood to report a collision (rho = −0.18, $p < 0.05$). Higher viral load was associated with being less likely to be a current driver (rho = −0.15, $p < 0.05$) and less days driven per week (rho = −0.22, $p < 0.01$). Finally, depressive symptoms were not associated with any driving variables (all p values > 0.05).

Several associations between driving habits and cognitive variables emerged in the total sample ($N = 260$; Table 3). Current driver status was not associated with any cognitive variables (p values > 0.05). Licensure was positively related to the better speed of processing ($p < 0.01$) and global cognition ($p < 0.01$). Days driven per week were positively associated with the better speed of processing ($p < 0.05$) and motor function ($p < 0.05$). The self-reported driving experience was positively associated with better performance in all seven cognitive domains (p values < 0.05) as well as with global cognition ($p < 0.01$). Self-reported driving quality was positively associated with the better speed of processing ($p < 0.01$), executive function ($p < 0.05$), motor function ($p < 0.01$), and global cognition ($p < 0.01$). Among those that reported currently driving regardless of license status ($n = 212$), greater miles driven per year was positively associated with the better speed of processing ($p < 0.01$), working memory/attention ($p < 0.01$), executive function ($p < 0.01$), motor function ($p < 0.01$), global cognition ($p < 0.01$), as well as with not having a cognitive impairment ($p < 0.01$). Collisions, times ticketed, and times pulled over were not associated with any cognitive variables (p values > 0.05). We also examined whether crashes per miles driven per year (crashes divided by miles per year driven) were associated with any of the cognitive domains, and no significant correlations emerged (all p values > 0.05). Given that speed of processing was the cognitive domain consistently associated with driving variables, a posthoc multivariable model was conducted examining the association of speed of processing with driving exposure (i.e., days driver per week), adjusting for variables associated with either variable (i.e., viral load, education, income, race). Note that a sample-based speed of processing Z score was used rather than the normatively corrected T score, given that race and education were variables in the model. The model showed that higher education ($B = 0.19$, $p = 0.04$) and income ($B = 0.34$, $p < 0.01$) were associated with greater days driven per week, while the speed of processing was not significant ($p = 0.12$).

Given that age may impact associations between driving and cognitive function, we conducted posthoc analyses by repeating the prior correlations among only those who were aged 50+ ($n = 153$), and results were almost identical to original correlations in the full sample. Current driver status was not associated with any cognitive variables (p values > 0.05). License status was positively associated with the better speed of processing ($p < 0.01$), working memory/attention ($p < 0.05$), and global cognition ($p < 0.05$). Days driven per week were positively associated with better executive function ($p < 0.05$), speed of processing ($p < 0.05$), motor function ($p < 0.05$), and global cognition ($p < 0.05$). The self-rated driving experience was positively associated with the speed of processing ($p < 0.05$), working memory/attention ($p < 0.05$), and global cognition ($p < 0.05$). Self-rated driving quality was positively associated with the speed of processing ($p < 0.05$) and motor function ($p < 0.05$). Among the older PLWH who reported currently driving regardless of license status ($n = 127$), greater miles driven per year was positively associated with better executive function ($p < 0.01$), speed of processing ($p < 0.01$), working memory/attention ($p < 0.01$), motor function ($p < 0.05$) and global cognition ($p < 0.01$), as well as less likelihood to have cognitive impairment ($p < 0.01$). Collisions, times ticketed, and times pulled over were not associated with any cognitive variables (p values > 0.05).

Aim 2: driving habits and health-related quality of life

Several associations between driving habits and HRQoL domains emerged in the total sample ($N = 260$; see Table 4). Current driving was positively related to social functioning ($p < 0.02$) and cognitive functioning ($p < 0.05$) HRQoL domains. Licensure was positively associated with social functioning ($p < 0.01$) and negatively associated with the health transition ($p < 0.05$) HRQoL domain. Days driven per week was positively associated with the social functioning ($p < 0.05$) HRQoL domain. The self-reported driving experience was positively related to the health distress ($p < 0.05$) HRQoL domain. Self-reported driving quality was positively associated with general health perception ($p < 0.01$), physical functioning ($p < 0.01$), social functioning ($p < 0.01$), cognitive functioning ($p < 0.01$), and health distress ($p < 0.01$) HRQoL domains. Among those that reported currently driving regardless of license status ($n = 212$), greater miles driven per year was negatively associated with energy/fatigue ($p < 0.05$) while times being pulled over was positively associated with social functioning ($p < 0.05$) and role functioning ($p < 0.05$) HRQoL domains.

Given the positive association found between days driven per week and the social functioning HRQoL domain (as well as consistent associations between this HRQoL domain and other driving habits), multivariable linear regression was conducted in the full sample (see Table 4). Covariates included variables associated with days driven per week (i.e., race, income, education) and the social functioning HRQoL domain score (i.e., income, depression score, Global Mean *T*). The overall regression was significant ($F[6, 251] = 16.79$, $p < 0.001$, $R^2 = 0.29$, adjusted $R^2 = 0.27$). Results showed a significant association between days driven per week and social functioning, such that a greater number of days driven per week was associated with higher social functioning scores. All covariates were significant, except income and education. Given that depressive symptoms and cognitive functioning may potentially influence the association of driving exposure and HRQoL or serve as potential mechanisms whereby days per week are associated with social functioning, two posthoc analyses were conducted. Interactions between both depression and global cognitive function with days per week were examined in the initial regression model and neither were significant ($p = 0.27$ and 0.68, respectively). We then conducted two regression models predicting social functioning: one with only days driven per week and one with days driven per week, depression, and cognitive function. In the first model days per week was significant ($B = 1.56$, $p < 0.01$), and in the second model all three variables were significant, but the effect of days per week was attenuated ($B = 1.11$, $p = 0.02$).

Discussion

This study explored driving habits and driving outcomes and their relationship with cognition and HRQoL domains (e.g., mental health, social functioning) in middle-aged and older PLWH, who were mostly African Americans of low SES. We found that the vast majority of our sample drove, including many without a valid driver's license. Among other factors, lack of licensure may be attributed to PLWH's socioeconomic constraints (Vance et al., 2015) given that most of our sample had annual household incomes of less than $20,000, an assumption supported by the significant association found between education and income with licensure status, as well as several other driving variables. This association resonates with the complexities (e.g., poverty, limited social resources) faced by PLWH that may be especially exacerbated among African Americans in the Deep South where this study was conducted (Quinn et al., 2017; Reif et al., 2017); in fact, such health disparities that may comprise brain health may account for the higher prevalence (58%) of cognitive impairment observed in this study, compared to the normal range observed in the literature between 30 and 50% of those with HIV (Waldrop et al., 2021). Other demographic associations with valid licensure included white race and older age. Interestingly, those with better immune functioning (i.e., higher current CD4+ lymphocyte count and lower viral load) reported fewer collisions and were more likely to be current drivers (respectively), suggesting that better health may facilitate driving fitness. However, a counterintuitive finding was that those with a better history of immune functioning (i.e., higher nadir CD4+ lymphocyte counts) were less likely to be currently licensed drivers. This unexpected finding could be confounded by complexities not examined in the current study (e.g., date of nadir CD4).

Relationships among driving variables showed expected results. Associations between self-rated driving experience and driving quality extend prior work by showing that the perceptions of PLWH regarding their driving relate to their actual driving habits and exposure. As expected, those who drive more were more likely to have a collision, be pulled over, and receive a ticket. These associations all confirm that our driving measures were tapping into intended constructs and that participants were accurately reporting their information.

Examining the relationship between driving habits and cognitive performance showed several interesting results. Speed of processing was the cognitive domain with the most consistent associations with driving variables. Better speed of processing was associated with higher rates of licensure, greater self-reported driving experience, better driving quality, and greater days driven per week and miles driven per year. Thames et al. (2013) found slower baseline speed of processing was related to increased driving errors in a driving simulator. Thus, remediating this cognitive ability via speed of processing training in older PLWH may yield favorable driving outcomes (Pope et al., 2018). Our adjusted multivariable model of days driven per week showed that speed of processing was not significant, while education and income were significant, suggesting that these social determinants of health confound relationships between cognition and driving. Similarly, for working memory/attention, higher scores were associated with greater self-reported driving experience and more miles driven per year. Whether examined as a single factor (Marcotte et al., 2004; Vance et al., 2014) or as a component of a larger battery used to create classifications (Marcotte et al., 2006), decreased working memory/attention is consistently associated with worse driving outcomes. Similarly, better executive function and motor skills were associated with greater driving exposure (i.e., days driven per week and miles per year). All cognitive domains were associated with greater self-reported driving experience, and several domains were associated with better self-reported driving quality. Classification with NCI was related to fewer miles driven per year. This mirrors the literature on cognition and driving among PLWH (Marcotte et al., 2004,; 2006; Vance et al., 2014) and overall our findings suggest that those with better cognitive functioning may be more fit to drive and thus may elect to drive more.

Our study was among the first to examine the relationship between driving habits and HRQoL among PLWH. Overall, we found that greater self-reported driving experience and/or better driving quality, as well as greater driving exposure (i.e., drive more days per week and miles per year), was related to better HRQoL. The most consistent pattern was with the social functioning HRQoL domain, such that better social function was associated with being a current and licensed driver, driving more days per week, reporting better driving quality, and being pulled over more (which is likely a function of driving more). Even in the context of important covariates such as demographics, depression, and cognitive functioning, greater driving exposure (days driven per week) was an independent correlate of social functioning. We also found that the association between driving exposure and social functioning was attenuated by depression and cognitive function, suggesting these may be potential pathways whereby driving may impact HRQoL. This association between frequent driving and increased social functioning is particularly relevant since active engagement in social activities is a key component of successful aging (Cosco et al., 2013; Fazeli et al., 2020). Previous studies measuring mobility and life space, or the size of a person's physical and social environment, have shown that limited life space is associated with older age, low income, and rural residence (Johnson et al., 2020; Peel et al., 2005). Further, people lacking driving mobility are less likely to travel within and beyond their city (i.e., have limited life space), whether due to age-related physical limitations, less access to public transportation, or lack of disposable income for activities (Peel et al., 2005). Limited driving mobility is tied to reduced social engagement, which can mean less participation in out-of-home activities such as shopping, entertainment trips, going to restaurants, and visiting with friends (Qin et al., 2020). Thus, driving cessation is associated with a higher risk of social isolation in older adults, which can lead to poor health outcomes, such as worsened physical health, cognitive decline, and depressive symptoms (Chihuri et al., 2016; Edwards et al., 2009; Qin et al., 2020). Social isolation poses a significant risk for older adults, which may be heightened for older PLWH, perhaps due to HIV-related stigma (Greene et al., 2018; Marziali et al., 2020; Miles et al., 2011); thus the associations between social functioning and driving mobility among older PLWH should be further explored. Consistent with the literature on a bidirectional association between health status and driving habits, our results imply that better HRQoL may contribute to better on-road driving, as those with better HRQoL may exhibit greater physical, cognitive, and social health needed to be higher-quality, more experienced drivers. Further, declining health may lead to driving cessation, and in turn driving cessation may result in poor health outcomes. Further study and analysis are needed to discern these dynamics.

Taken together, our findings corroborate the connection between cognitive ability and driving ability in HIV (Vance et al., 2014) and other populations, such as commercial motor vehicle drivers (McManus et al., 2016) and also builds upon prior work by demonstrating associations between cognition and self-reported driving habits, suggesting cognitive functioning likely impact all facets of driving, including self-evaluations of driving.

Implications for practice

Based on these findings, a few implications for clinical practice should be considered. This study was conducted in an urban area with limited, but available, bus, taxi, and ride share service and no rail system. Roughly 81% of the sample reported currently driving, 18% without a valid license, highlighting barriers to transportation and travel faced by PLWH. A potential difficulty with transportation must be factored into care for PLWH, as their medical access may be dependent upon the schedules and driving routes of friends, family, and limited public transportation (Kempf et al., 2010). As a result, this population may be more prone to cancelations or missed appointments and may be unable to access some facilities, clinics, and offices. Setting aside other related factors, such as vehicle possession, expense, and reliability, even PLWH who currently drive to their appointments may be doing so without licensure, thus increasing their legal and financial risk when accessing care. It may be desirable to provide bus passes or taxi fares to encourage compliance with appointments.

Additionally, given the relationship between cognition and self-reported driving habits, it appears those PLWH experiencing worse cognitive functioning may have less active driving habits, meaning those with greater needs for care likely have the least access to that care. Practitioners may be more accommodating to these barriers by using techniques such as appointment clustering, the practice of scheduling multiple appointments in one day or timeframe to efficiently leverage transportation, or using telehealth when appropriate. Anecdotally, participants in the present study often reported doing this on their own accord, scheduling specialist consultations, clinic visits, and research appointments with our research group on the same day to access more care with less travel. The current COVID pandemic has revealed the possibilities offered by telemedicine.

Given the relationship between cognition, driving behavior, and social functioning, this study emphasizes the role in which mobility can support social functioning, and social functioning may also support cognition (Waldrop et al., 2021). During the COVID-19 epidemic, this may be especially important. Even with access to transportation, many people had to physically isolate themselves from socializing with others, impacting their social connection to family and friends. As most of our participants were of lower SES, it is not clear what kind of access they had to technologies or physical resources (e.g., outdoor areas to congregate) that allowed them to remain connected socially. It has been hypothesized that this lack of socialization, and perhaps social isolation due to HIV-related stigma, may have a detrimental impact on brain health and cognitive functioning, which could further exacerbate HIV-related cognitive impairment (Vance et al., 2021).

Implications for research

Although this study is among the first to examine the relationship between self-reported driving habits, cognition, and HRQoL in middle-aged and older PLWH, future studies would benefit from objectively assessing driving behaviors obtained from crash records, simulated and on-road driving performance, and GPS software which is more ecologically valid. This combined approach may provide a more complete picture of driving in older PLWH. It also provides opportunities for comparison between objective driving tasks and subjective driving evaluations, which may provide insight into PLWH's metacognitive abilities relative to the driving task.

HIV's impact on cognitive aging is a key theoretical underpinning and justification for the present study which examined cognition, HRQoL, and self-reported driving habits in middle-aged and older PLWH only. Future studies could build upon these findings by comparing HIV+ and HIV− participants of similar ages as well as drivers affected by non-HIV chronic illness. Expanding this design to include participants without HIV may further elucidate the impact of HIV-related cognitive impairments on self-reported driving habits, and HRQoL.

Finally, reduced ability to drive can decrease one's life space and hinder the ability to socially interact and engage with others as has been seen in other studies (Byles et al., 2015). Such social isolation can negatively impact mood and increase depressive symptomatology, and even impact cognition. Studies show that social engagement is important for maintaining optimal cognitive function (Fazeli et al., 2014); and such cognitive function is vital for sustained safe driving ability (Edwards et al., 2008; Vance et al., 2014). A deeper dive into these reciprocal relationships is warranted.

Strengths and limitations

The above findings should be considered in the context of the study's strengths and limitations. Four strengths are noted. First, this study is among the first to examine cognition, HRQoL, and self-reported driving habits in PLWH. Second, the study had a relatively large sample for a single-site project with this population. Third, participants were sampled from the Deep South, a region that is considered the epicenter of HIV/AIDS in the US (Reif et al., 2017). Lastly, the findings align substantially with previous work in cognition and simulated or on-road driving performance in PLWH.

Study limitations are also noted. While this study's cross-sectional and correlational approach is an important first step, it does not account for the possible bidirectional relationships among the variables in question. Future longitudinal studies would be best suited to examine the temporal associations among driving habits, cognition, and HRQoL in PLWH. Also, a significant number of participants were of lower SES, a factor that may impact generalizability. Further, while sampling from the Deep South is a strength, this region's unique challenges (e.g., high poverty, greater burden among African Americans, limited reliable public transportation) pose problems for generalizability in other contexts (Quinn et al., 2017). Similarly, while such factors may have contributed to the high rate of cognitive impairment in our sample, it is also possible that since recruitment materials for the parent study advertised that this study was focused on cognitive training, people who were concerned about their cognitive health may have been more likely to call about the study; this could have introduced a recruitment bias in that those who participated may have been more cognitively vulnerable. Another limitation is that we did not explore in depth the qualitative reasons for not being a current driver and not having a license, and thus future work should examine such data for a better understanding of barriers to driving among PLWH in the Deep South. Another limitation is that we did not assess substance use, which could have complex associations with cognition, driving, and indicators of quality of life. Lastly, the associations among driving experience, driving quality, and HRQoL were based upon self-report measures and therefore may be subjective; older PLWH perceiving greater HRQoL may also perceive themselves to be better, more experienced drivers.

Conclusion

Most participants currently drove, but a substantial number were driving without licensure, a variable that impacted other important driving habits. Cognitive impairments experienced by older PLWH were associated with self-reported driving habits, suggesting such impairments contribute to all facets of driving, including driving self-evaluation. Driving limitations may in turn impact PLWH's access to care and well-being. Future research should incorporate self-reported driving habits into other investigations of cognition, HRQoL, and driving performance.

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