Title

Social and Neighborhood Context Moderates the Associations Between Processing Speed and Driving Mobility: A 10-year Analysis of the ACTIVE Study.

Journal
Journal of Aging and Health, 35(9_suppl)

Authors
Pope, Caitlin
Wheeler, Katie
Bell, Tyler
et al.

Publication Date
2023-10-01

DOI
10.1177/08982643231163907

Peer reviewed

HHS Public Access
Author manuscript
J Aging Health. Author manuscript; available in PMC 2024 December 09.

Published in final edited form as:
J Aging Health. 2023 October ; 35(9 Suppl): 26S–39S. doi:10.1177/08982643231163907.

Social and Neighborhood Context Moderates the Associations between Processing Speed and Driving Mobility: A 10-year Analysis of the ACTIVE study

Caitlin N. Pope, PhD[1], **Katie M. Wheeler**[2], **Tyler R. Bell, PhD**[3], **Brooke E. Carroll**[2], **Lesley A. Ross, PhD**[4], **Michael Crowe, PhD**[2], **Shelia R. Black, PhD**[5], **Olivio J. Clay, PhD**[2], **Karlene K. Ball, PhD**[2]

[1]Department of Health, Behavior and Society, University of Kentucky

[2]Department of Psychology, University of Alabama at Birmingham

[3]Department of Psychiatry, University of California, San Diego

[4]Department of Psychology, Clemson University

[5]Department of Psychology, The University of Alabama

Abstract

Objectives: Processing speed is essential to functional independence in later life, such as driving a vehicle. Few studies have examined processing speed and driving mobility in the context of racial differences and social determinants of health (SDoH). This study characterized the longitudinal association between processing speed and driving mobility, and how it varied by race and SDoH.

Methods: Using data from the control arm of the Advanced Cognitive Training in Vital Elderly study (n=581, 24.5% Black), multilevel models examined longitudinal associations between processing speed and driving mobility outcomes (driving space, exposure, and difficulty). Race and SDoH moderations were explored.

Results: Decline in processing speed measures was associated with increased self-reported driving difficulty, but only for older adults with below-average to average scores for neighborhoods and built environments and social community context SDoH domains.

Discussion: Findings emphasize the influence of physical and social environmental characteristics on processing speed and driving mobility.

Keywords

older drivers; everyday functioning; driving mobility; cognition; social determinants

---

Corresponding author: Caitlin N. Pope, 151 Washington Ave Bowman Hall RM 356 Lexington KY, 40506, caitlin.pope@uky.edu.

Declaration of Conflicting Interests
Dr. Karlene Ball owns stock in the Visual Awareness Research Group (formerly Visual Awareness, Inc.), and Posit Science, Inc., the companies that market the Useful Field of View Test and speed of processing training software. Posit Science acquired Visual Awareness, and Dr. Ball continues to collaborate on the design and testing of these Assessment and training programs as a member of the Posit Science Scientific Advisory Board. The other authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Driving a vehicle is a key instrumental activity of daily living that helps to promote and sustain functional independence in older age. In the United States (U.S.) driving a personally owned vehicle also remains a preferred and primary source of transportation for adults ages 65 and older (Bayne et al., 2021; Shen et al., 2017). Reduction or restriction in the ability to drive is subsequently associated with a multitude of negative health outcomes including decreased life space (Marottoli et al., 2000), depression (Ragland et al., 2005), social isolation (Qin et al., 2020), chronic co-morbidities (Chihuri et al., 2016), and early mortality (Edwards, Perkins, et al., 2009). As such, assessing changes in driving may help identify people in need of early intervention to sustain functional independence in later life. One way to capture changes in driving is by measuring *driving mobility*, a broad term that captures how individuals move around in their environment via driving a vehicle. Common indicators of driving mobility include extreme behaviors such as driving cessation (the permanent retirement from driving), or subtler behaviors reflecting driving restriction such as driving space (extent to which an individual drives in their environment beyond their property), driving exposure (total number of challenging conditions an individual encounters while driving), and driving difficulty (the level of difficulty experienced by an individual when driving in challenging conditions; Ball et al., 1998; Edwards, Myers, et al., 2009).

Many factors in later life are important to driving. One major factor is cognitive functioning, which is susceptible to age and disease-related decline. Across studies and samples of drivers cognitive functioning is a consistent predictor of driving outcomes such as risky driving behavior, driving errors, and crash risk (Anstey & Wood, 2011; Clay et al., 2005; Daigneault et al., 2002; Dickerson et al., 2019; Edwards et al., 2008; Mäntylä et al., 2009; Pope et al., 2016). Furthermore, studies have linked cognitive functioning strongly to other measures of everyday mobility such as walking and life space (how much one moves around in their home and external environment; De Silva et al., 2019; Kuo et al., 2007). Understanding the cognitive predictors of driving mobility specifically may help inform interventions to sustain functional independence.

Previous studies have examined relations between cognitive functioning and driving mobility with three major limitations to overcome. First, previous studies on cognitive functioning and driving mobility have focused on cognitive composites (Choi et al., 2014). This leaves a lack of clarity as to which cognitive domains are most relevant to driving mobility. In the Advanced Cognitive Training in Independent and Vital Elderly (ACTIVE) study, speed of processing (the rate at which sensory-level information is used for higher-level cognitive processing; Vance, 2009) training improved driving mobility (greater weekly driving frequency and lower likelihood of driving cessation) post training while training in other cognitive domains did not (Ball et al., 2010; Edwards, Myers, et al., 2009; Ross et al., 2016; Ross et al., 2017). As such, future work is needed to understand the role of processing speed which is vulnerable to age and disease-related decline and appears modifiable (Tucker-Drob, 2011). Second, studies have focused on driving cessation, an extreme change in driving mobility (Dugan & Lee, 2013; Edwards et al., 2010; Edwards et al., 2008). While an important outcome as older adults will live beyond their driving cessation by 6 to 11 years (Dickerson et al., 2019; Foley et al., 2002), this is an extreme change to measure. Capturing subtler behaviors, such as driving space, driving difficulty, and driving exposure, may be more helpful in detecting restricted driving in its earliest forms. Third, previous studies have frequently overlooked the importance of how race or social determinants of health (SDoH) may help to understand how cognitive function is associated with driving mobility outcomes across individuals (Babulal et al., 2018).

As with other areas of health and quality of life, the broader context of an individual's environment and how it may influence person-level indicators of health and functioning cannot be ignored as we consider how the association between cognitive functioning and driving mobility may change across an individual's lifespan. While social ecological (Bronfenbrenner, 1977; McLeroy et al., 1988) and public health (Alvidrez et al., 2019; Dahlgren & Whitehead, 1991; Dahlgren & Whitehead, 2021) frameworks used to conceptualize the interconnectedness of SDoH with individual outcomes show the nested nature of a person's physical health outcomes within larger socio-economic, cultural, and environmental conditions, empirical studies are needed to statistically assess the relationship between SDoH indicators and mobility outcomes. Recently, a few studies have connected individual SDoH indicators (accumulated wealth and transportation characteristics of the neighborhood and built environment) to increased likelihood of driving restriction and cessation in both cross-sectional and longitudinal samples (Vivoda et al., 2017; Vivoda et al., 2020). Lacking is a more comprehensive and longitudinal assessment of many different SDoH indicators with driving mobility that represent all five SDoH domains recognized by Healthy People 2030 (economic stability, education access and quality, health care access and quality, neighborhood and built environment, and social and community context; Healthy People 2030). Additionally, incorporating race in the conversation of SDoH is imperative as individuals of racial and ethnic minorities in the U.S. are disproportionately burdened by health disparities, a downstream effect of structural racism (Henderson & Wells, 2021; Jones, 2002), compounded with the growing diversification of the U.S. population (Federal Interagency Forum on Aging-Related Statistics, 2016). Babulal et al. (2018) concluded that among the few studies that included racial differences as a study focus (n = 4 out of 18 that included race as a covariate and reported it), being a member of a racial or ethnic minority group significantly increased an individual's risk of experiencing driving reduction, restriction, and cessation. Given the importance of accounting for SDoH indicators when assessing racial differences in cognitive functioning and decline (Gross et al., 2015; Marsiske et al., 2013; Sisco et al., 2015; Wilson et al., 2016), it is also important to consider the unique contributions of both race and SDoH when investigating driving mobility.

Building upon these empirical gaps, this study aimed to better characterize the longitudinal association between cognitive functioning, specifically processing speed, and driving mobility in older age while accounting for both race and SDoH in a multi-site U.S. sample of older adults ages 65 and older. Based on prior research, we hypothesized that worse processing speed would be associated with worse driving mobility. Additionally, while less research has focused on racial and SDoH differences, we hypothesized that Black older adults and those with lower scores on SDoH indicators would have worse driving mobility compared to White older adults and those with higher scores on SDoH indicators.

Author Manuscript

Author Manuscript

Author Manuscript

Method

Participants

The analytic sample consisted of participants from the no-contact control arm of the randomized control study ACTIVE (ClinicalTrials.gov Identifier NCT00298558). The purpose of the ACTIVE study was to test the efficacy of three cognitive training programs (vs. a no-contact control) on older adults' cognition and everyday functioning. Recruitment occurred from March 1998 to October 1999 across 6 sites in the U.S.: Birmingham, Alabama; Detroit, Michigan; Indianapolis, Indiana; Baltimore, Maryland; State College, Pennsylvania; and Boston, Massachusetts. Participants included community-dwelling adults aged 65 years and older who did not present the following exclusion criteria: (1) potential cognitive impairment indicated by Mini Mental Status Examination (MMSE) < 23 or reported a diagnosis of dementia; (2) functional impairment (i.e., required extensive assistance with activities of daily living like dressing, bathing, or personal hygiene; Morris et al., 1997); (3) self-reported diagnosis of stroke in the last 12 months; (4) self-reported diagnosis of certain cancers and/or current chemo- or radiation therapy; (5) self-reported problems in vision (e.g., difficulty reading news or visual acuity worse than 20/50), hearing, or communication that would prevent full participation in the intervention or outcome assessments; (6) received cognitive training previously; or (7) had been unable to meet time requirements of the study. Additional details regarding the ACTIVE study are discussed elsewhere (Jobe et al., 2001).

For this study, only participants in the control arm who did not participate in cognitive training were used (n = 704). Of the 704 randomized to the control arm, 15 did not self-identify as Black or White race and 94 were not currently driving at baseline. Furthermore, 6 were missing data on cognitive function and driving mobility, leaving an analytic sample of 589 older adults. The analytic sample had a baseline mean age of 74 years (SD = 5.76, range: 65 – 91) and were majority women (71%, n = 420). On average, participants reported 13.6 years of education (SD = 2.68, range from 6 – 20 years). Additional details on the sample are presented in Table 1. Using package "simr" in R version 4.0 (Green & MacLeod, 2016), our sample had a 91% power to detect a fixed effect of at least an f^2 of .01 using mixed linear models.

Measures

Processing speed.—Processing speed was measured using the Useful Field of View (UFOV®) test (Ball & Owsley, 1993) and Digit Symbol Substitution Task (DSST; Weschler, 1939). UFOV® subtests 1-4 measures speed of visual processing across increasing levels of cognitive demand (target discrimination only, target discrimination in a divided attention task, target discrimination with divided attention and distraction, more difficult target discrimination with divided attention and distraction). Scores ranged from 16.67 – 500 milliseconds (ms) per trial with longer presentation times to achieve a threshold indicating worse performance. Progression through the subtests is based upon a threshold time required to perform each task (75% accuracy) less than the maximum score of 500 milliseconds. For the current study, UFOV® subtests 2-4 scores were summed to generate a UFOV® composite score which was reverse scored so that higher scores indicated better performance (multiplying scores by −1). UFOV® subtest 1, the subtest with the least cognitive demand, was at ceiling for most participants at baseline, showing no variability, and was not included in the summed score. The DSST is a neuropsychological measure of processing speed (motor, perceptual, and visual scanning) and attention. Participants are instructed to copy corresponding symbols into spaces below a row of numbers using a matching key within 90 seconds (s). The number of correct symbols matched are summed with higher scores indicating better performance.

Driving Mobility: Driving mobility outcomes were obtained from a validated questionnaire which assessed driving space, driving exposure, and driving difficulty (Edwards, Myers, et al., 2009; Owsley et al., 1999).

Driving space.—Participants reported the extent to which they personally drove in their environment. The time frame for driving within their environment varied by the distance from their property or residence. During the last 7 days was used for driving to places beyond their property or residence, immediate neighborhood, or town or community. During the last 2 months was used for driving to places beyond their county or city, state, and region of the U.S (customized based upon study site). The responses were binary coded such that yes was coded as 1 and no was coded as 0. The responses were then summed to create a summary score ranging from 0 – 6 with higher scores indicating a larger driving space.

Driving exposure.—Participants reported if they drove in challenging driving conditions during the previous 2 months. These driving conditions included driving alone, in the rain, driving in rush hour traffic, at night, making left-hand turns across oncoming traffic, merging into traffic on a highway or expressway, on high-traffic roads, and making lane changes. The responses were binary coded such that encountering the challenging driving condition while driving was coded as 1 and not encountering the condition was coded as 0. The responses were then summed to create a summary score ranging from 0 – 8. High scores reflected more challenging conditions encountered while driving.

Difficulty driving in typical situations.—Participants reported their level of difficulty driving alone, making lane changes, and making left-hand turns across oncoming traffic. The responses were presented on a 4-point Likert scale ranging from 1 “No difficulty at all” to 4 “Extreme difficulty”. Based on Edwards, Myers, et al. (2009), driving difficultly in typical situations was indexed by summing the response scores for three items, with scores ranging from 4 to 12. Higher scores indicated more difficulty driving in typical driving situations.

Difficulty driving in high-risk situations.—Participants reported their level of difficulty driving in rush hour traffic, on high-traffic roads, at night, in the rain, and merging into traffic on a highway or expressway. The responses were presented on a 4-point Likert scale ranging from 1 “No difficulty at all” to 4 “Extreme difficulty”. Based on Edwards, Myers, et al. (2009), driving difficultly in high-risk situations was indexed by summing the response scores on the five items, with scores ranging from 4 to 20. Higher scores indicated more difficulty driving in high-risk driving situations.

Covariates

Demographics.—Participants self-reported demographics at their baseline visit of the ACTIVE study. This included age, gender, years of education, and race. The self-reported race options included White, Black, Asian, Native American, Pacific Islander, American Indian or Alaskan Native, Bi-racial, and Other.

General health.—The 36-item Short Form Survey (SF-36) was used to measure general health (Choi et al., 2013; Hays & Shapiro, 1992; Stewart et al., 1992; Ware & Sherbourne, 1992). The SF-36 general health scale is comprised of 5 items that are recoded and averaged to obtain scores ranging from 0 to 100. Higher scores indicated better self-reported health.

Visual Acuity.—Far visual acuity was measured using standard procedures for a GoodLite Model 600A light box with the Early Treatment Diabetic Retinopathy Study chart. Participants were instructed to read the letters on the chart from 10 feet away with no corrective lenses and then when applicable, with corrective lenses. The scores ranged from 0 – 90 based upon how many letters were correctly discriminated, with higher scores indicating better visual acuity (Ball et al., 2002).

Functional Ability.—Functional ability was measured using self-reported difficulties in basic and instrumental activities of daily living (IADLs), including difficulties in the last 7 days on 19 tasks spanning meal preparation, housework, finances, health care, telephone use, shopping, travel, need for assistance in dressing, personal hygiene, and bathing (Hirdes et al., 2004; Landi et al., 2000).

Social Determinants of Health (SDoH) Composites.—SDoH was captured using 5 domains recognized by Healthy People 2030: economic stability, education access and quality, health care access and quality, neighborhood and built environment, and social and community context. These composites were previously created by Clay et al. (2022) via principal components analysis with varimax rotation resulting in orthogonal, uncorrelated factors. These factors included both person-level data from the baseline visit of the ACTIVE study and neighborhood-level data sources obtained from linked 2000 U.S. Census block group level information via geocoding of participant addresses (Clay et al., 2022; Meyer et al., 2017; Sisco & Marsiske, 2012). Other sources of information used to provide contextual information included the North American Industry Classification System (NAICS) data for a list of businesses by type in a zip code (e.g., grocery stores) and occupational information from the Dictionary of Occupational Titles to code occupational status (Clay et al., 2022; Meyer et al., 2017; Sisco & Marsiske, 2012). SDoH indicators were assessed at one time-point and did not account for change over time.

Economic stability was comprised of the percent of people with college degree, the presence of sports and recreation instruction, median home value, and median rent in zip code. *Education access and quality* was comprised of self-reported years of education and occupation converted into ratings describing degree of involvement in data, people, and things from 1 (minimal) to 8 (a lot) from self-reported occupation. *Health care access and quality* was measured by the number of doctors, number of hospitals, number of pharmacies and other drug stores, number of services for the elderly and persons with disabilities, and number of supermarkets and other (non-convenience) grocery stores in zip code. *Neighborhood and built environment* was comprised of the number of owner occupied homes and the number of single unit dwellings in zip code. *Social and community context* was comprised of the number of golf courses and country clubs, supermarkets and other (non-convenience) grocery stores, and the percent of white residents in zip code. Direction and weights of factor loading can be found in Clay et al. (2022).

Procedure

All study procedures were approved by site International Review Boards. The details of the ACTIVE study procedures are provided in greater detail elsewhere (Jobe et al., 2001). After an initial screening, eligible participants provided an in-person informed consent followed by a baseline assessment of everyday habits, psychosocial function, health, and physical and cognitive function. Health questionnaires, including the driving mobility questionnaire were completed during the baseline assessment. Participants were then randomized into one of three training arms (memory, reasoning, or speed of processing training) or the control arm. All study arms completed assessments at immediate posttest and 1, 2, 3, 5, and 10 years after the intervention trial concluded. The driving mobility questionnaire was not administered at immediate posttest.

Analysis Plan

Multilevel models were used to examine the association of processing speed, race, and SDoH with driving mobility outcomes. The form of the full multilevel model equation is below with three major variable sets:

$$\text{Level 1 (Individual Scores Over Time)}: Y_{ij[}\text{Driving mobility outcome across individuals}(i)\text{and over Time}(j)] = \beta 0_i + \beta 1[\text{time}]_{ij} + \beta 2[\text{Baseline processing speed} * \text{Time}]_{ij} + \beta 3[\text{Change in processing speed}]_{ij} + \beta 4[\text{general health}]_{ij} + \beta 5[\text{visual acuity}]_{ij} + \beta 6[\text{functional ability}]_{ij} + \beta 7[\text{Race/SDoH} * \text{change in processing speed}]_{ij} + e_{ij}$$

$$\text{Level 2} \quad \beta 0_i[\text{Baseline driving mobility outcome}] = \gamma 00 + \gamma 01[\text{Baseline processing speed}] + \gamma 02[\text{race/SDoH}] + \gamma 03[\text{gender}] + \gamma 04[\text{Site}] + \gamma 05[\text{Baseline age}] + \gamma 06[\text{Race/SDoH} * \text{baseline processing speed}] + \mu_i$$

Where Y_{ij} represents driving mobility outcomes (driving space, driving exposure, driving difficulty, and driving avoidance) for an individual (i) at each time point (j), $\beta0_i$ is the baseline processing speed test score for each individual, $\gamma00$ is the sample mean of the driving mobility outcome and $\beta1$ reflects the yearly rate of change in driving mobility tested by our time variable of years after baseline (age at follow-up - age at baseline); $\gamma01$ estimates the association of baseline processing speed and baseline level of the driving mobility outcome; $\gamma02$ estimates the association of race and SDoH variables (race and each SDoH variable tested in independent models) and baseline level of the driving mobility outcome. $\gamma03$, $\gamma04$, $\gamma05$ estimate the association of gender, site, and baseline age on the baseline level of the driving mobility outcome, respectively. $\beta2$ estimates the association of baseline processing speed and change in the driving mobility outcome. $\beta3$ estimates the association of occasion-specific changes in processing speed after baseline and change in driving mobility outcomes. β4, β5, and β6 estimates the association of general health, visual acuity, and functional ability and occasion-specific change in driving mobility outcome. Independent models additionally examined the moderating effects of race and SDoH variables by adding interaction terms with baseline processing speed and change in processing speed (γ06, β6). For descriptive purposes, the effect of baseline or change in processing speed were provided at specific values of significant moderators. For race interactions, specific estimates were provided for Black and White individuals. For SDoH interactions, specific estimates were provided at statistically meaningful levels of the SDoH composite, including the mean and +/− 1 SD. Lastly, e_{ij} and μ_i represent the error within individuals (Level 1 error) and between individuals (Level 2 error), respectively.

Data were analyzed in SPSS Version 28 using GENLINMIXED function (IBM Corp., 2021) for multilevel models. All mixed models included random intercepts and effect sizes were estimated using standardized betas for each variable, for which $f^2 \geq .02$, $\geq .15$, and $\geq .35$ typically correspond to small, medium, and large effect sizes, respectively (Cohen, 1988). Statistical significance was determined at $p<.05$. All *p*-values were corrected for multiple testing using Holmes-Bonferroni procedures.

Results

Demographics and Baseline Characteristics

Table 1 shows a summary of demographics and baseline characteristics of the analytic sample, which is further stratified by race. Overall, Black older adults were more likely to be female, have less education, and have worse visual acuity when compared to White older adults. Black older adults reported on average a smaller driving space than White older adults but did not differ significantly on other baseline driving mobility outcomes. Black older adults performed worse on both measures of processing speed when compared to White older adults. Black older adults had worse SDoH profiles than White older adults, with lower scores in economic stability, education access and quality, neighborhood and built environment, and social community context.

Main Results

Model results are summarized in Table 2 and 3 for analyses examining associations of DSST and UFOV, respectively. Full model results, including main effects and covariate effects, are shown in Supplementary Table 1. White older adults had greater driving space (β = .24, SE = .06, $p < .001$) while women had less driving space (β = −.19, SE = .05, $p < .001$). Women also had less difficulty driving in high-risk driving situations (β = −.22, SE = .06, $p < .001$). Of the SDoH composites, individuals living in areas with greater health care access and quality also had greater driving space (β = .08, SE = .02, $p < .001$). Lastly, over time driving space increased (β = .48, SE = .02, $p < .001$) and difficulty driving in high-risk driving situations decreased (β = −.12, SE = .02, p < .001).

Driving Space

Baseline Processing Speed.: Baseline levels of driving space were not associated with baseline levels of DSST or UFOV® (*p*s > .05). Changes in driving space were also not significantly associated with baseline levels of DSST or UFOV® (ps > .05). These associations did not vary by race or SDoH composites (ps > .05).

Change in Processing Speed.: Decline in DSST was associated with decline in driving space (β = .15, 95%CI [.06, .24], $p = .007$). This association did not vary by race or SDoH variables. For change in UFOV®, a moderation was found with economic stability (β =−.05, 95%CI [.01,.09], $p = .018$). Decline in UFOV® was associated with an increase in driving space among individuals with average (mean level, β = −.08, 95%CI [−.14, −.03], $p < .001$) and above average scores for economic stability (+1 SD, β = −.15, 95%CI [−.22, −.07], $p < .001$), but not in individuals with average or below average scores for economic stability (−1 SD, $p = .617$; see Supplemental Figure 1).

Driving Exposure

Baseline Processing Speed.: Baseline levels of DSST, but not UFOV® ($p = .905$) was negatively associated with baseline levels of driving exposure (β = −.16, 95%CI [−.26, −.06], $p = .024$). Baseline levels of DSST and UFOV® were not associated with changes in driving exposure (ps > .05). These associations were not moderated by race or SDoH composites (ps > .05).

Change in Processing Speed.: Social and community context moderated the association of change in DSST with change in driving exposure (β =.05, 95%CI [.02,.09], $p = .016$). Decline in DSST was associated with greater driving exposure in people with above average scores for social and community context (+1 SD, β = .06, 95%CI [.02, 09], $p = .001$), but not in people with below average (−1 SD) to average (mean level) scores for social community context (ps > .05; see Supplemental Figure 2). Change in UFOV® was not associated with change in driving exposure ($p = .963$) nor showed significant moderations by race or SDoH composites (ps > .05).

Driving Difficulty in Typical Driving Situations

Baseline Processing Speed.—The association between baseline DSST and baseline difficulty driving in typical driving situations was moderated by the neighborhood and built environment (β = .13, 95%CI [.06, .20], $p < .001$). Better baseline DSST was associated with less driving difficulty in typical situations in people with below average (−1 SD, β = −.35, 95%CI: [−.51, −.19], $p < .001$) and average scores for neighborhood and built environments (mean level, β = −.16, 95%CI [−.27, −.05], $p = .008$), but not in people with above average scores for neighborhood and built environments (+1 SD, β = .02, 95%CI: [−.12, .18], $p = .795$; see Supplemental Figure 3). Baseline UFOV® was not associated with baseline levels of driving difficulty in typical driving situations ($p = .676$) nor showed significant moderations by race or SDoH composites (ps >.05). Baseline levels of DSST and UFOV® were not associated with change in driving difficulty in typical situations (ps > .05).

Change in Processing Speed.—Change in DSST was associated with change in driving difficulty in typical driving situations (β = −.24, 95%CI [−.35, −.12], $p < .001$), and was moderated by the neighborhood and built environment (β = .13, 95%CI [.06, .20], $p < .001$). As shown in Figure 1, decline in DSST was associated with increased driving difficulty in people with below average (−1 SD, β = −.49. 95%CI [−.65, −.34], $p < .001$) and average scores for neighborhood and built environments (mean level, β = −.29, 95%CI [−.40, −.19], $p < .001$), but not in people with above average scores for neighborhood and built environments (+1 SD, β = −.09, 95%CI [−.25, .07], $p = .259$). Decline in UFOV® was not associated with change in driving difficulty in typical situations ($p = .518$) nor showed significant moderations by race or SDoH composites (*p*s > .05).

Driving Difficulty in High-Risk Situations

Baseline Processing Speed.—The association between baseline levels of DSST and baseline levels of difficulty driving in high-risk situations was moderated by social and community context (β = .07, 95%CI [.02, .13], $p = .048$). Better baseline levels of DSST was associated with less difficulty driving in high-risk situations in people with below average scores for social and community context (−1 SD, β = −.35, 95%CI [−.68, −.01], $p = .040$; see Supplemental Figure 4) but not in people with average (mean level, β = −.03, 95%CI [−.29, .23], $p = .818$) or above average scores for social and community context (+1 SD, β = .29, 95%CI [−.08, .65], $p = .127$). Baseline DSST was similarly moderated by neighborhood and built environment (β = .08, 95%CI [.04, .12], $p = .048$). Baseline levels of UFOV® were not associated with baseline levels of driving difficulty in high-risk driving situations ($p = .469$) nor showed significant moderations by race or SDoH composites (*p*s > .05). Baseline levels of DSST and UFOV® were not associated with changes in driving difficulty in high-risk situations (*p*s > .05).

Change in Processing Speed.—The association between change in DSST and change in difficulty driving in high-risk situations was moderated by social and community context (β = .07, 95%CI [.03, .12], $p = .024$). As shown in Figure 2, declines in DSST were associated with greater difficulty driving in high-risk situations in people with below average scores for social and community context (−1 SD, $\beta = -.61$, 95%CI[−.90, −.33], $p < .001$), but not in people with average (mean level, $p = .833$) or above average scores for social and community context (+1 SD, $\beta = .04$, 95%CI [−.33, .42], $p =.834$). Changes in UFOV® were not associated with change in driving difficulty in high-risk situations ($p = .496$) nor showed significant moderations by race or SDoH composites (*p*s >.05).

Discussion

As the population of adults ages 65 and older in the U.S. continues to increase and diversify, understanding how driving mobility changes over later life is imperative for promoting and sustaining safe and functional independence (Babulal et al., 2018; Choi et al., 2013). Cognitive functioning, specifically processing speed, has been frequently studied as a sensitive predictor of declines in driving performance and crash risk in older drivers (Anstey & Wood, 2011; Clay et al., 2005; Daigneault et al., 2002). Less understood is if processing speed is associated with driving mobility (driving space, driving exposure, and driving difficulty) in later life, and how the association may differ by race or SDoH. Investigating how race and SDoH are associated with driving mobility will help provide needed insight into mobility and transportation inequities that are impacting functional independence in older age (Babulal et al., 2018; Vivoda et al., 2017; Vivoda et al., 2020).

Below we summarize our findings and compare them to previous literature to inform study implications.

Overall, we found that people with declining processing speed were more likely to have difficulty with driving mobility when living in poorer social community contexts and neighborhood built environments. Specifically, declines in processing speed were associated with increased perceived difficulty driving in high-risk driving situations for older adults living in below-average social and community contexts. For older adults living in below-average neighborhoods and built environments, greater declines in processing speed were associated with increased difficulty driving in typical driving situations. Interestingly, race did not moderate associations between processing speed and driving mobility. This should not be interpreted to mean that race is negligible in the association between processing speed and driving mobility, when in fact *the opposite is true.* In our sample we found that most SDoH composite scores were lower in Black older adults than White older adults, meaning that Black older adults were more likely to face the negative outcomes of declining processing speed because they lived in poorer social community contexts and neighborhood built environments compared to White older adults who were less likely to live in those contexts. Furthermore, we unexpectedly found that people who lived in areas of average and above average economic stability and social community contexts had increases in driving space and exposure, respectively, when they faced processing speed declines – likely due to greater socioeconomic resources to maintain driving independence. Because Black older adults were less likely to live in these supportive contexts, they were less likely to experience greater driving mobility after facing declines in processing speed. Altogether, lower available SDoH confers greater risk to driving mobility, which is more likely to affect members of historically disenfranchised racial and ethnic minority groups such as Black older adults.

Our study contrasts the limited number of previous studies focused on racial and ethnic differences and driving mobility (Babulal et al., 2018). As summarized in Babulal et al. (2018), most prior studies have limited their focus to driving cessation, an extreme measure of driving mobility. In addition to one other recent study (Babulal et al. (2020), we expanded this prior work by examining more subtle variations in driving mobility captured by driving space, driving exposure, and difficulty driving. Like Babulal et al. (2020), we found that Black older adults reported more restricted driving space compared to White older adults. However, Babulal et al. (2020) also found race differences in driving exposure and driving difficulty and used naturalistic driving methodology to validate self-reported findings that showed Black older adults in that sample had a faster rate of change in driving exposure metrics when compared to White older adults. When comparing findings, it is important to note recruitment differences between the current study and Babulal et al. (2020), which recruited from a sample of cognitively normal people who participated in a longitudinal clinical cohort affiliated with an Alzheimer Disease Research Center. These individuals may have had greater variability in driving mobility compared to the community sample recruited to meet the study criteria for the ACTIVE study. Additional research is needed to understand driving mobility by race and ethnicity across clinical and community samples to properly meet the needs of all older adults with varying levels of health burden. In addition to examining driving mobility differences beyond cessation, we expanded prior findings by including measures of SDoH rather than just self-reported race as a proxy variable. We also examined how SDoH moderated a well-known cognitive risk predictor, processing speed, of driving safety.

One of the biggest contributions of this study is our focus on SDoH as a moderator of the association between processing speed and driving mobility. To our knowledge, these associations have not yet been explored to this degree. From our findings, social and community context and the neighborhood and the built environment were of the most importance, especially with perceived difficulty in driving in typical and high-risk driving situations. Additionally, economic stability was a significant moderator between changes in processing speed and driving space. Few studies exist in this area, yet similar findings were seen in Vivoda et al. (2017) which focused on the built transportation environment in relation to driving reduction and cessation in older adults. In that study Vivoda et al. (2017) found that increased odds of driving reduction and cessation over time was associated with increases in roadway density and congestion (measured via geographic information system data and other congestion indices). Additionally, Vivoda et al. (2020) also found less accumulated wealth was cross-sectionally associated with a higher likelihood of engaging in driving restriction and cessation compared to those with higher wealth. While the specific mechanisms behind how indices of the social and built environment act upon driving mobility are still unknown, the amount and type of resources an individual has access to in their life should be investigated further. Based upon the cumulative disadvantage theory, the structural and environmental resources accessible to an individual builds upon itself over time (Dannefer, 1987, 1988; O'Rand, 1996). These structural and environmental resources directly impact one's ability to accumulate individual wealth and has direct implications for not only income, but also health and well-being in relation to mobility (Ferraro & Kelley-Moore, 2003). Individuals with less individual wealth or of lower socioeconomic status may be less able to continue affording a personal vehicle making them dependent on family members and friends or alternative forms of transportation. For example, in a sample of majority lower income Black older adults with HIV, Pope et al. (2022) found that lower reported annual income was significantly associated with lower likelihood of car ownership or having access to a car. Similarly, individual wealth is correlated with the overall wealth of the environment the individual lives in. Through exclusionary housing policies and practices such as blockbusting and redlining (Henderson & Wells, 2021), neighborhoods and communities create residential segregation and disparities that could contribute to fewer resources that would support driving mobility despite processing speed decline in later age. Further research specifically focusing on the mechanisms behind the influential factors of environment on both cognition and driving mobility is needed.

Lastly, our findings also add to studies examining measures of processing speed and driving mobility. Specifically, our study findings suggest that the DSST was a more sensitive indicator of driving mobility. Given the prior research on UFOV®, a lack of association between UFOV® and driving mobility outcomes was unexpected. Across different community and clinical-based samples of older drivers UFOV® has been shown to be a reliable indicator of crash-risk and associated with driving cessation (Ball et al., 2021; Clay et al., 2005; Edwards et al., 2010; Edwards et al., 2008). One potential explanation for this unexpected finding could be due, in part, to the difference in driving outcomes of interest (self-reported driving behaviors and patterns vs. the likelihood of having a crash). While driving self-regulatory behaviors are commonly performed by older adults in efforts to reduce their overall crash risk, it remains unknown how advantageous these behaviors are in the context of other factors like cognitive dysfunction or impairment (Aschenbrenner et al., 2022; Ross et al., 2009). Our findings suggest that declines in processing speed may not be the most salient indicator of whether a driver will continue to drive, especially if that driver lives in an environment that is more economically resourced and less racially diverse.

Another possible explanation for the differences seen between DSST and UFOV® with driving mobility within our sample could be attributed to the psychometric differences behind the two measures. The DSST is a pencil and paper task originally developed to distinguish individuals with and without brain damage (Jaeger, 2018; Weschler, 1939). The task relies on multiple abilities including scanning (motor, perceptual, and visual), attention, and dexterity (Jaeger, 2018; Marsiske et al., 2013). While used as a measure of processing speed, the measure is polyfactorial, tapping into higher-order cognitive processes such working memory and executive functioning (Jaeger, 2018; Lezak et al., 2004). Impairment in any of the many processes the DSST taps into likely contributes to its sensitivity to change over time. In the driving literature, the DSST has also been shown to be a significant predictor of driving cessation and driving performance in later life (Edwards et al., 2008). UFOV® on the other hand is a computer-based task designed to detect age-related decline and visual difficulties relevant to everyday functioning that are not detected by traditional vision tests (Ball & Owsley, 1993; Wood & Owsley, 2014). Most notably, it is not reliant on dexterity as seen with pencil and paper tasks. Prior research on UFOV® has focused on its predictive ability of driving (crash reports, on-road driving abilities, and driving simulator abilities) and functional abilities (Ball et al., 2010; Clay et al., 2005; Edwards et al., 2006; Wood & Owsley, 2014). It also has been routinely used as an outcome of interest in cognitive-training studies that have extended the speed of processing training paradigm from the ACTIVE study (Meneses et al., 2018; Vance et al., 2021). UFOV® taps into visual processing, attention, and executive functioning, much like DSST (Wood & Owsley, 2014). While less research has been conducted on UFOV®'s sensitivity to change over time, a previous evaluation by Lunsman et al. (2008) also using data from the control arm of the ACTIVE study showed similar trajectories of change between DSST and UFOV® over a 5-year period. Noted was a low correlation between the two measures as well as differences in predictors. Finally, the evidence behind racial bias in neuropsychological testing and the role of education access and quality (Lamar et al., 2020) when comparing the psychometric differences behind DSST and UFOV® is important. Evidence of racial differences has been noted for both tests (Jaeger, 2018; Lunsman et al., 2008) and it is unknown is how this inherent methodological bias may skew interpretations of race differences in driving mobility. Our study did not find that race significantly moderated associations between measures of processing speed and driving mobility, which would be expected if such measurement bias was present. Nevertheless, race-based measurement bias should be considered when interpreting differences in processing speed between older Black and White adults.

While the current study has many strengths, including a large longitudinal multi-site sample, multiple indicators of both processing speed and driving mobility, and SDoH composites composed of multiple indicators, there are notable limitations. The sample recruited for the ACTIVE study was positively biased as exclusion criteria screened for undergoing major medical conditions and treatment, cognitive impairment, and serious functional impairment. This original study design may have contributed to a higher-functioning sample that may not be generalizable to the larger population of older adults with more complex health needs and environmental constraints. More longitudinal research in samples with more complex health profiles is needed to further understand longitudinal associations between processing speed, driving mobility, and race and SDoH.

Another limitation is the lack of diversity of measured race and SDoH related cultural factors that may be associated with both cognitive functioning and driving mobility. As noted by Marsiske et al. (2013), small race effects were present in cognitive measures even after accounting for education and health indicators, suggesting there remains unmeasured cultural factors that cannot be accounted for in the ACTIVE study. This includes an indicator of socioeconomic status, financial burden, or employment over time. While the SDoH composites included in the current study are proxies of socioeconomic status, they are only a brief snapshot of the older adult's environment from the 2000 census and do not directly reflect early life factors or changes in environment thereafter. This is an important limitation for the current study, but also a limitation that is reflective of the Healthy People 2030 core objectives of economic stability where baseline data is only currently available in terms of assessment for measurable change. Future studies assessing change in stability over time and how it is associated with both cognition and driving mobility is needed. To fully understand these findings through the lens of cumulative disadvantage theory (Dannefer, 1987, 1988; O'Rand, 1996) in respect to driving mobility, life course indicators are needed.

Lastly, given the study relied on self-reported driving mobility behaviors, participant recall bias is of potential concern. Participants with a MMSE of 23 or less were excluded from the baseline sample, but this does not account for how cognition may have declined over time and the indirect effects of that cognitive decline on the individual's ability to recall their daily driving behavior retrospectively. Additionally, bias may have existed in terms of overconfidence in driving abilities and could have attributed to the perceived driving difficulty in risky driving situations. Naturalistic studies that rely on non-obtrusive recordings of driver behavior and patterns could remedy this potential limitation as seen in Babulal et al. (2020) who found evidence of mobility decline using both measurement methods.

Conclusions

Using the data from the control arm of the ACTIVE study we characterized the longitudinal associations between two measures of processing speed, multiple SDoH composites, and driving mobility outcomes over 10 years. Overall, the SDoH composites reflecting characteristics of the social and built environment had the strongest influence on the association between processing speed and driving mobility. Findings suggest that those in below-average to average social and community contexts and neighborhoods and built environments may be the most vulnerable in terms of their driving mobility when experiencing declines in processing speed. Given Black older adults in our sample were less likely to live in these supportive environmental contexts, they may be more likely to experience poorer driving mobility in the face of declines in processing speed. Mechanistic longitudinal work focused on race and SDoH in the context of cognition and driving mobility is needed. Applying a life course approach to understanding the influence of race and SDoH on driving mobility will provide insight into the context behind driving mobility behaviors.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Funding

This work was supported by the National Institute on Aging (R01AG054520). The ACTIVE intervention trials were supported by grants from the National Institute on Aging and the National Institute of Nursing Research to Hebrew Senior Life (U01NR04507), Indiana University School of Medicine (U01NR04508), Johns Hopkins University (U01AG14260), New England Research Institutes (U01AG14282), Pennsylvania State University (U01AG14263), the University of Alabama at Birmingham (U01AG14289), and the University of Florida (U01AG14276). Dr. Caitlin Pope is supported by a research career development award (K12DA035150: Building Interdisciplinary Research Careers in Women's Health Program-BIRCWH) from the National Institutes of Health Office of Research on Women's Health and the National Institute on Drug Abuse. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

References

Alvidrez J, Castille D, Laude-Sharp M, Rosario A, & Tabor D (2019). The National Institute on Minority Health and Health Disparities Research Framework. American Journal of Public Health, 109(S1), S16–s20. 10.2105/ajph.2018.304883 [PubMed: 30699025]

Anstey KJ, & Wood J (2011). Chronological age and age-related cognitive deficits are associated with an increase in multiple types of driving errors in late life. Neuropsychology, 25(5), 613–621. 10.1037/a0023835 [PubMed: 21574713]

Aschenbrenner AJ, Murphy SA, Doherty JM, Johnson AM, Bayat S, Walker A, Peña Y, Hassenstab J, Morris JC, & Babulal GM (2022). Neuropsychological correlates of changes in driving behavior among clinically healthy older adults. The Journals of Gerontology: Series B, gbac101. 10.1093/geronb/gbac101

Babulal GM, Stout SH, Williams MM, Rajasekar G, Harmon A, Vivoda J, Zuelsdorff M, Benzinger TLS, Morris JC, Ances B, & Roe CM (2020). Differences in Driving Outcomes Among Cognitively Normal African American and Caucasian Older Adults. Journal of Racial and Ethnic Health Disparities, 7(2), 269–280. 10.1007/s40615-019-00655-z [PubMed: 31686371]

Babulal GM, Williams MM, Stout SH, & Roe CM (2018). Driving Outcomes among Older Adults: A Systematic Review on Racial and Ethnic Differences over 20 Years. Geriatrics, 3(1). 10.3390/geriatrics3010012

Ball K, Berch DB, Helmers KF, Jobe JB, Leveck MD, Marsiske M, Morris JN, Rebok GW, Smith DM, Tennstedt SL, Unverzagt FW, & Willis SL (2002). Effects of cognitive training interventions with older adults: a randomized controlled trial. Journal of the American Medical Association, 288(18), 2271–2281. 10.1001/jama.288.18.2271 [PubMed: 12425704]

Ball K, Edwards JD, Ross LA, & McGwin G Jr. (2010). Cognitive training decreases motor vehicle collision involvement of older drivers. Journal of the American Geriatrics Society, 58(11), 2107–2113. 10.1111/j.1532-5415.2010.03138.x [PubMed: 21054291]

Ball K, & Owsley C (1993). The useful field of view test: a new technique for evaluating age-related declines in visual function. Journal of the American Optometric Association, 64(1), 71–79. [PubMed: 8454831]

Ball KK, Clay OJ, Edwards JD, Fausto BA, Wheeler KM, Felix C, & Ross LA (2021). Indicators of crash risk in older adults: A longitudinal analysis from the ACTIVE study. Journal of Aging and Health, epub ahead of press.

Ball KK, Owsley C, Stalvey B, Roenker DL, Sloane ME, & Graves M (1998). Driving avoidance and functional impairment in older drivers. Accident Analysis & Prevention, 30(3), 313–322. 10.1016/S0001-4575(97)00102-4 [PubMed: 9663290]

Bayne A, Siegfried A, Beck LF, & Freund K (2021). Barriers and facilitators of older adults' use of ride share services. J Transp Health, 21. 10.1016/j.jth.2021.101055

Bronfenbrenner U (1977). Toward an experimental ecology of human development. American Psychologist, 32(7), 513–531.

Chihuri S, Mielenz TJ, DiMaggio CJ, Betz ME, DiGuiseppi C, Jones VC, & Li G (2016). Driving Cessation and Health Outcomes in Older Adults. Journal of the American Geriatrics Society, 64(2), 332–341. 10.1111/jgs.13931 [PubMed: 26780879]

Choi M, Lohman MC, & Mezuk B (2014). Trajectories of cognitive decline by driving mobility: evidence from the Health and Retirement Study. International Journal of Geriatric Psychiatry, 29(5), 447–453. 10.1002/gps.4024 [PubMed: 24022894]

Choi M, Mezuk B, Lohman MC, Edwards JD, & Rebok GW (2013). Gender and racial disparities in driving cessation among older adults. Journal of Aging and Health, 25(8 Suppl), 147s–162s. 10.1177/0898264313519886 [PubMed: 24385634]

Clay OJ, Ball KK, Wheeler KM, Crowe M, Marsiske M, Dean LT, Thorpe RJ, Jones R, Owens JH, Rebok GW, & Willis SL (2022). Evaluating Social Determinants of Health Domains and Their Predictive Validity Within Black/African American and White Older Adults From the Active Trial. Journal of Aging and Health, 0(0), 08982643221111205. 10.1177/08982643221111205

Clay OJ, Wadley VG, Edwards JD, Roth DL, Roenker DL, & Ball KK (2005). Cumulative Meta-analysis of the Relationship Between Useful Field of View and Driving Performance in Older Adults: Current and Future Implications. Optometry and Vision Science, 82(8). https://journals.lww.com/optvissci/Fulltext/2005/08000/Cumulative_Meta_analysis_of_the_Relationship.15.aspx

Dahlgren G, & Whitehead M (1991). Policies and strategies to promote social equity in health. Institute for Future Studies.

Dahlgren G, & Whitehead M (2021). The Dahlgren-Whitehead model of health determinants: 30 years on and still chasing rainbows. Public Health, 199, 20–24. 10.1016/j.puhe.2021.08.009 [PubMed: 34534885]

Daigneault G, Joly P, & Frigon JY (2002). Executive functions in the evaluation of accident risk of older drivers. Journal of Clinical and Experminental Neuropsychology, 24(2), 221–238. 10.1076/jcen.24.2.221.993

Dannefer D (1987). Aging as Intracohort Differentiation: Accentuation, the Matthew Effect, and the Life Course. Sociological Forum, 2, 211–236.

Dannefer D (1988). Differential Gerontology and the Stratified LIfe Course: Conceptual and Methodological Issues. Annual Review of Gerontology and Geriatrics, 8, 3–36.

De Silva NA, Gregory MA, Venkateshan SS, Verschoor CP, & Kuspinar A (2019). Examining the Association between Life-Space Mobility and Cognitive Function in Older Adults: A Systematic Review. Journal of Aging Research, 2019, 3923574. 10.1155/2019/3923574 [PubMed: 31275650]

Dickerson AE, Molnar LJ, Bedard M, Eby DW, Berg-Weger M, Choi M, Grigg J, Horowitz A, Meuser T, Myers A, O'Connor M, & Silverstein NM (2019). Transportation and Aging: An Updated Research Agenda to Advance Safe Mobility among Older Adults Transitioning From Driving to Non-driving. Gerontologist, 59(2), 215–221. 10.1093/geront/gnx120 [PubMed: 28958085]

Dugan E, & Lee CM (2013). Biopsychosocial risk factors for driving cessation: Findings from the Health and Retirement Study. Journal of Aging and Health, 25(8), 1313–1328. 10.1177/0898264313503493 [PubMed: 24067290]

Edwards JD, Bart E, O'Connor ML, & Cissell G (2010). Ten years down the road: predictors of driving cessation. Gerontologist, 50(3), 393–399. 10.1093/geront/gnp127 [PubMed: 19726733]

Edwards JD, Myers C, Ross LA, Roenker DL, Cissell GM, McLaughlin AM, & Ball KK (2009). The longitudinal impact of cognitive speed of processing training on driving mobility. Gerontologist, 49(4), 485–494. 10.1093/geront/gnp042 [PubMed: 19491362]

Edwards JD, Perkins M, Ross LA, & Reynolds SL (2009). Driving status and three-year mortality among community-dwelling older adults. The Journals of Gerontology: Series A, 64(2), 300–305. 10.1093/gerona/gln019

Edwards JD, Ross LA, Ackerman ML, Small BJ, Ball KK, Bradley S, & Dodson JE (2008). Longitudinal Predictors of Driving Cessation Among Older Adults From the ACTIVE Clinical Trial. The Journals of Gerontology: Series B, 63(1), P6–P12. 10.1093/geronb/63.1.P6

Edwards JD, Ross LA, Wadley VG, Clay OJ, Crowe M, Roenker DL, & Ball KK (2006). The useful field of view test: Normative data for older adults. Archives of Clinical Neuropsychology, 21(4), 275–286. 10.1016/j.acn.2006.03.001 [PubMed: 16704918]

Federal Interagency Forum on Aging-Related Statistics. (2016). Older Americans 2016: Key Indicators of Well-Being. Retrieved 08/04/2022 from https://agingstats.gov/docs/LatestReport/Older-Americans-2016-Key-Indicators-of-WellBeing.pdf

Ferraro KF, & Kelley-Moore JA (2003). Cumulative Disadvantage and Health: Long-Term Consequences of Obesity? American Sociological Review, 68(5), 707–729. [PubMed: 22581979]

Foley DJ, Heimovitz HK, Guralnik JM, & Brock DB (2002). Driving Life Expectancy of Persons Aged 70 Years and Older in the United States. American Journal of Public Health, 92(8), 1284–1289. 10.2105/AJPH.92.8.1284 [PubMed: 12144985]

Green P, & MacLeod CJ (2016). SIMR: an R package for power analysis of generalized linear mixed models by simulation [10.1111/2041-210X.12504]. Methods in Ecology and Evolution, 7(4), 493–498. 10.1111/2041-210X.12504

Gross AL, Mungas DM, Crane PK, Gibbons LE, MacKay-Brandt A, Manly JJ, Mukherjee S, Romero H, Sachs B, Thomas M, Potter GG, & Jones RN (2015). Effects of education and race on cognitive decline: An integrative study of generalizability versus study-specific results. Psychology and Aging, 30(4), 863–880. 10.1037/pag0000032 [PubMed: 26523693]

Hays RD, & Shapiro MF (1992). An overview of generic health-related quality of life measures for HIV research. Qual Life Res, 1(2), 91–97. 10.1007/bf00439716 [PubMed: 1301123]

Healthy People 2030. Social Determinants of Health. U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion,. Retrieved 12/01/2022 from https://health.gov/healthypeople/priority-areas/social-determinants-health

Henderson S, & Wells R (2021). Environmental Racism and the Contamination of Black Lives: A Literature Review. Journal of African American Studies, 25(1), 134–151. 10.1007/s12111-020-09511-5

Hirdes JP, Fries BE, Morris JN, Ikegami N, Zimmerman D, Dalby DM, Aliaga P, Hammer S, & Jones R (2004). Home care quality indicators (HCQIs) based on the MDS-HC. Gerontologist, 44(5), 665–679. 10.1093/geront/44.5.665 [PubMed: 15498842]

IBM Corp. (2021). IBM SPSS Statistics for Windows. In (Version 28.0) IBM Corp.

Jaeger J (2018). Digit Symbol Substitution Test: The Case for Sensitivity Over Specificity in Neuropsychological Testing. Journal of Clinical Psychopharmacology, 38(5), 513–519. 10.1097/jcp.0000000000000941 [PubMed: 30124583]

Jobe JB, Smith DM, Ball K, Tennstedt SL, Marsiske M, Willis SL, Rebok GW, Morris JN, Helmers KF, Leveck MD, & Kleinman K (2001). ACTIVE: a cognitive intervention trial to promote independence in older adults. Controlled Clinical Trials, 22(4), 453–479. 10.1016/s0197-2456(01)00139-8 [PubMed: 11514044]

Jones CP (2002). Confronting Institutionalized Racism. Phylon (1960-), 50(1/2), 7–22. 10.2307/4149999

Kuo HK, Leveille SG, Yu YH, & Milberg WP (2007). Cognitive function, habitual gait speed, and late-life disability in the National Health and Nutrition Examination Survey (NHANES) 1999-2002. Gerontology, 53(2), 102–110. 10.1159/000096792 [PubMed: 17090975]

Lamar M, Lerner AJ, James BD, Yu L, Glover CM, Wilson RS, & Barnes LL (2020). Relationship of Early-Life Residence and Educational Experience to Level and Change in Cognitive Functioning:

Results of the Minority Aging Research Study. The Journals of Gerontology: Series B, 75(7), e81–e92. 10.1093/geronb/gbz031

Landi F, Tua E, Onder G, Carrara B, Sgadari A, Rinaldi C, Gambassi G, Lattanzio F, Bernabei R, & Bergamo S.-H. S. G. o. (2000). Minimum data set for home care: a valid instrument to assess frail older people living in the community. Medical Care, 38(12), 1184–1190. 10.1097/00005650-200012000-00005 [PubMed: 11186297]

Lezak MD, Howieson DB, Loring DW, & Fischer JS (2004). Neuropsychological assessment. Oxford University Press, USA.

Lunsman M, Edwards JD, Andel R, Small BJ, Ball KK, & Roenker DL (2008). What predicts changes in useful field of view test performance? Psychology and Aging, 23(4), 917–927. 10.1037/a0013466 [PubMed: 19140660]

Mäntylä T, Karlsson MJ, & Marklund M (2009). Executive control functions in simulated driving. Applied Neuropsychology, 16(1), 11–18. 10.1080/09084280802644086 [PubMed: 19205943]

Marottoli RA, de Leon CFM, Glass TA, Williams CS, Cooney LM Jr., & Berkman LF (2000). Consequences of driving cessation: Decreased out-of-home activity levels. The Journals of Gerontology: Series B, 55(6), S334–340. 10.1093/geronb/55.6.s334

Marsiske M, Dzierzewski JM, Thomas KR, Kasten L, Jones RN, Johnson KE, Willis SL, Whitfield KE, Ball KK, & Rebok GW (2013). Race-related disparities in 5-year cognitive level and change in untrained ACTIVE participants. Journal of Aging and Health, 25(8 Suppl), 103S–127S. 10.1177/0898264313497794 [PubMed: 24385632]

McLeroy KR, Bibeau D, Steckler A, & Glanz K (1988). An ecological perspective on health promotion programs. Health Education Quarterly, 15, 351–377. [PubMed: 3068205]

Meneses K, Benz R, Bail JR, Vo JB, Triebel K, Fazeli P, Frank J, & Vance DE (2018). Speed of processing training in middle-aged and older breast cancer survivors (SOAR): results of a randomized controlled pilot. Breast Cancer Research and Treatment, 168(1), 259–267. 10.1007/s10549-017-4564-2 [PubMed: 29128897]

Meyer OL, Sisco SM, Harvey D, Zahodne LB, Glymour MM, Manly JJ, & Marsiske M (2017). Neighborhood Predictors of Cognitive Training Outcomes and Trajectories in ACTIVE. Research on Aging, 39(3), 443–467. 10.1177/0164027515618242 [PubMed: 26667987]

Morris JN, Fries BE, Steel K, Ikegami N, Bernabei R, Carpenter GI, Gilgen R, Hirdes JP, & Topinkova E (1997). Comprehensive clinical assessment in community setting: applicability of the MDS-HC. Journal of the American Geriatrics Society, 45(8), 1017–1024. 10.1111/j.1532-5415.1997.tb02975.x [PubMed: 9256857]

O'Rand AM (1996). The precious and the precocious: understanding cumulative disadvantage and cumulative advantage over the life course. Gerontologist, 36(2), 230–238. 10.1093/geront/36.2.230 [PubMed: 8920094]

Owsley C, Stalvey B, Wells J, & Sloane ME (1999). Older drivers and cataract: driving habits and crash risk. The Journals of Gerontology: Series A, 54(4), M203–211. 10.1093/gerona/54.4.m203

Pope CN, Ross LA, & Stavrinos D (2016). Association Between Executive Function and Problematic Adolescent Driving. Journal of Developmental and Behavioral Pediatrics, 37(9), 702–711. 10.1097/DBP.0000000000000353 [PubMed: 27661394]

Pope CN, Stavrinos D, Fazeli PL, & Vance DE (2022). Transportation Barriers and Health-Related Quality of Life in a Sample of Middle-Aged and Older Adults Living with HIV in the Deep South. AIDS and Behavior, 26(7), 2148–2158. 10.1007/s10461-021-03560-x [PubMed: 35066731]

Qin W, Xiang X, & Taylor H (2020). Driving Cessation and Social Isolation in Older Adults. Journal of Aging and Health, 32(9), 962–971. 10.1177/0898264319870400 [PubMed: 31431103]

Ragland DR, Satariano WA, & MacLeod KE (2005). Driving cessation and increased depressive symptoms. The Journals of Gerontology: Series A, 60(3), 399–403. 10.1093/gerona/60.3.399

Ross LA, Clay OJ, Edwards JD, Ball KK, Wadley VG, Vance DE, Cissell GM, Roenker DL, & Joyce JJ (2009). Do Older Drivers At-Risk for Crashes Modify Their Driving Over Time? The Journals of Gerontology: Series B, 64B(2), 163–170. 10.1093/geronb/gbn034

Ross LA, Edwards JD, O'Connor ML, Ball KK, Wadley VG, & Vance DE (2016). The Transfer of Cognitive Speed of Processing Training to Older Adults' Driving Mobility Across 5 Years. The Journals of Gerontology: Series B, 71(1), 87–97. 10.1093/geronb/gbv022

Ross LA, Freed SA, Edwards JD, Phillips CB, & Ball K (2017). The Impact of Three Cognitive Training Programs on Driving Cessation Across 10 Years: A Randomized Controlled Trial. Gerontologist, 57(5), 838–846. 10.1093/geront/gnw143 [PubMed: 28329859]

Shen S, Koech W, Feng J, Rice TM, & Zhu M (2017). A cross-sectional study of travel patterns of older adults in the USA during 2015: implications for mobility and traffic safety. BMJ Open, 7(8), e015780. 10.1136/bmjopen-2016-015780

Sisco S, Gross AL, Shih RA, Sachs BC, Glymour MM, Bangen KJ, Benitez A, Skinner J, Schneider BC, & Manly JJ (2015). The Role of Early-Life Educational Quality and Literacy in Explaining Racial Disparities in Cognition in Late Life. The Journals of Gerontology: Series B, 70(4), 557–567. 10.1093/geronb/gbt133

Sisco SM, & Marsiske M (2012). Neighborhood Influences on Late Life Cognition in the ACTIVE Study. Journal of Aging Research, 2012, 435826. 10.1155/2012/435826 [PubMed: 22966458]

Stewart AL, Sherbourne CD, Hays RD, Wells KB, Nelson EC, Kamberg C, Rogers WH, Berry SH, & Ware JE Jr. (1992). Summary and Discussion of MOS Measures. In Stewart AL & Ware JE Jr. (Eds.), Measuring Functioning and Well-Being: The Medical Outcomes Study Approach (pp. 345–371). Duke University Press.

Tucker-Drob EM (2011). Global and domain-specific changes in cognition throughout adulthood. Developmental Psychology, 47(2), 331–343. 10.1037/a0021361 [PubMed: 21244145]

Vance DE (2009). Speed of processing in older adults: a cognitive overview for nursing. Journal of Neuroscience Nursing, 41(6), 290–297. 10.1097/jnn.0b013e3181b6beda

Vance DE, Fazeli PL, Azuero A, Wadley VG, Raper JL, & Ball KK (2021). Can Individualized-Targeted Computerized Cognitive Training Benefit Adults with HIV-Associated Neurocognitive Disorder? The Training on Purpose Study (TOPS). AIDS and Behavior, 25(12), 3898–3908. 10.1007/s10461-021-03230-y [PubMed: 33733311]

Vivoda JM, Heeringa SG, Schulz AJ, Grengs J, & Connell CM (2017). The Influence of the Transportation Environment on Driving Reduction and Cessation. Gerontologist, 57(5), 824–832. 10.1093/geront/gnw088 [PubMed: 27342439]

Vivoda JM, Walker RM, Cao J, & Koumoutzis A (2020). How Accumulated Wealth Affects Driving Reduction and Cessation. Gerontologist, 60(7), 1273–1281. 10.1093/geront/gnaa039 [PubMed: 32346739]

Ware JE Jr., & Sherbourne CD (1992). The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Medical Care, 30(6), 473–483. [PubMed: 1593914]

Weschler D (1939). The Measurement of Adult Intelligence. The Williams & Wilkins Company.

Wilson RS, Rajan KB, Barnes LL, Weuve J, & Evans DA (2016). Factors related to racial differences in late-life level of cognitive function. Neuropsychology, 30(5), 517–524. 10.1037/neu0000290 [PubMed: 27149552]

Wood JM, & Owsley C (2014). Useful field of view test. Gerontology, 60(4), 315–318. 10.1159/000356753 [PubMed: 24642933]

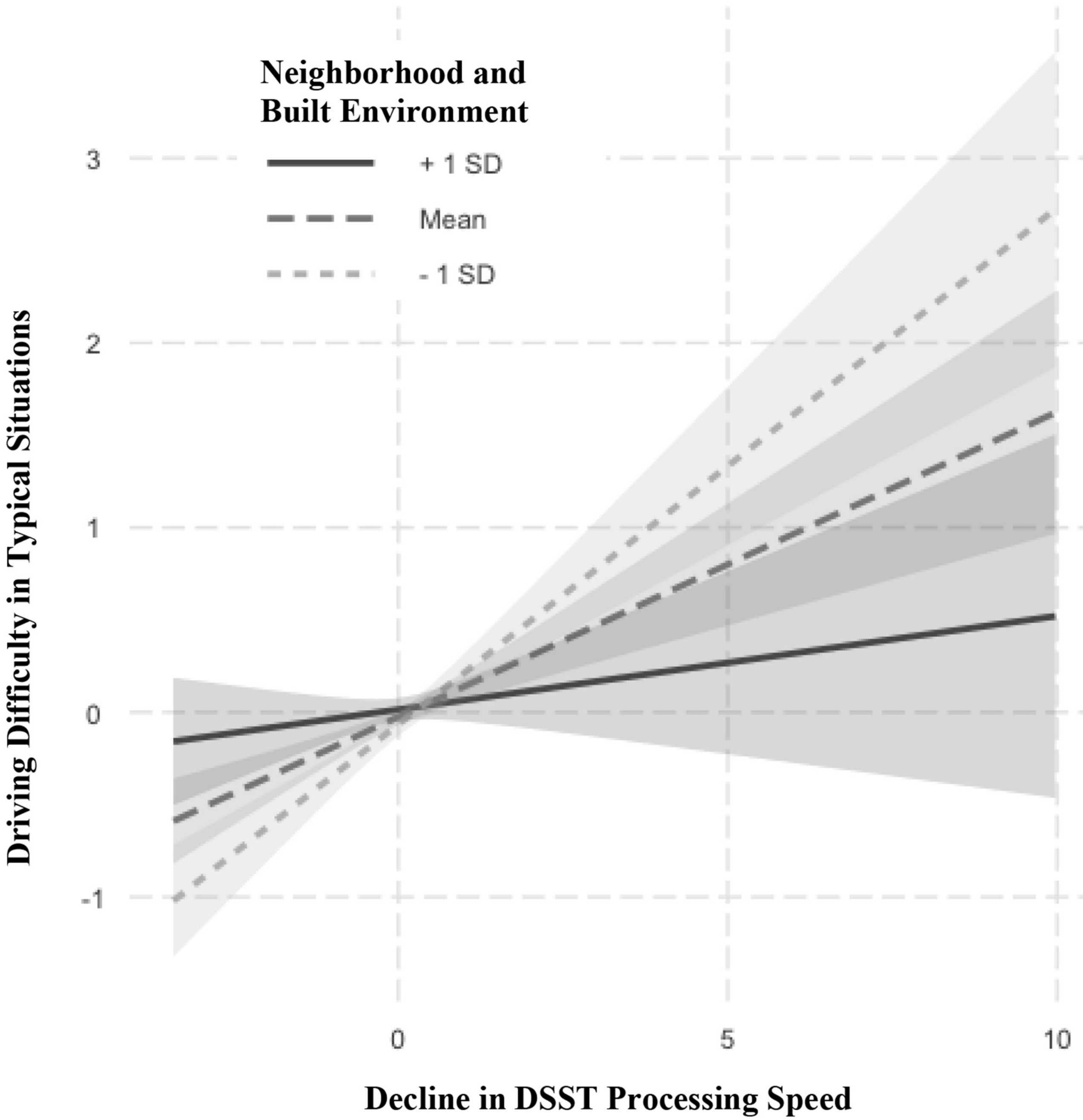

Figure 1. Changes in Digit Symbol Substitution and difficulty driving in typical driving situations over time by neighborhood and built environment.

Note. This figure shows how the neighborhood and built environment of which an individual resides moderates the association of (occasion-specific) changes in processing speed after baseline with (occasion-specific) changes in difficulty driving in typical driving situations. Positive numbers on the x-axis indicates greater processing speed decline. The loosely dashed line represents the mean level (average neighborhood and built environment); the densely dashed line represents 1 standard deviation below the mean (below average neighborhood and built environment); the solid line represents 1 standard deviation above the mean (above average neighborhood and built environment).

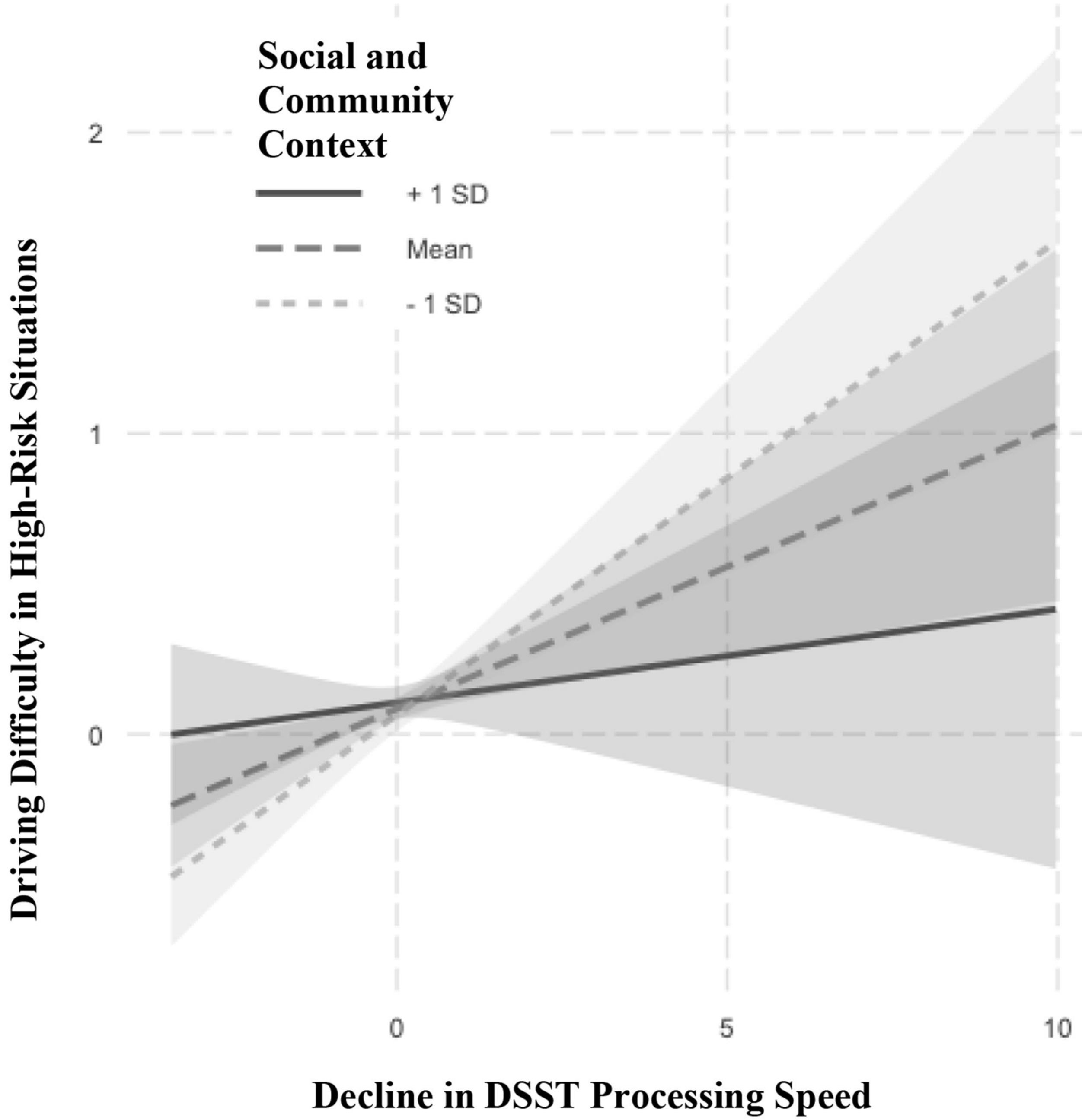

Figure 2. Changes in Digit Symbol Substitution and difficulty driving in high-risk situations over time by social and community context.

Note. This figure shows how the social and community context of which an individual resides moderates the association of (occasion-specific) changes in processing speed after baseline with (occasion-specific) changes in difficulty driving in high-risk driving situations. Positive numbers on the x-axis indicates greater processing speed decline. The loosely dashed line represents the mean level (average social and community context); the densely dashed line represents 1 standard deviation below the mean (below average social and community context); the solid line represents 1 standard deviation above the mean (above average social and community context).

Table 1.

Analytic Sample Characteristics

Variable	**Total (*n* =581)**	**White (*n* =447)**	**Black (*n* =142)**	***F or*** **X^2 Test**	***p*-value**
Age, mean (SD)	73.54 (5.76)	73.80 (5.80)	72.74 (5.57)	1.91	.056
Female sex, n (%)	420 (71%)	68.5 (306)	80.3% (114)	7.37	.007
Years of education, mean (SD)	13.61 (2.68)	13.76 (2.74)	13.14 (2.43)	2.42	.016
SF-36 general health, mean (SD)	69.85 (18.07)	69.56 (18.32)	66.70 (18.54)	1.63	.103
Days driven per week, mean (SD)	5.55 (1.84)	4.91 (2.74)	3.90 (3.17)	3.68	<.001
Functional Ability	20.35 (2.47)	20.37 (2.46)	20.28 (2.51)	.08	.933
Visual acuity	73.77 (11.65)	73.03 (11.89)	76.11 (10.90)	2.74	.006
Driving Space	3.38 (1.30)	3.46 (1.29)	3.15 (1.29)	2.49	.013
Driving Exposure	91.19 (15.74)	91.55 (15.26)	90.07 (17.20)	.98	.330
Difficulty Driving in Typical Driving Situations	3.11 (1.68)	3.13 (1.80)	3.06 (1.24)	.43	.666
Difficulty Driving in High-Risk Driving Situations	5.26 (3.75)	5.39 (3.82)	4.87 (3.49)	1.44	.150
DSST Processing Speed	40.90 (11.28)	42.13 (10.81)	37.06 (11.87)	4.75	<.001
UFOV® Processing Speed	−923.87 (283.26)	−908.15 (278.77)	−973.25 (292.49)	2.40	.017
Economic Stability	.04 (1.04)	.23 (1.06)	−.50 (.75)	7.62	<.001
Education and Occupational Status	−.06 (1.02)	.04 (1.11)	−.37 (.59)	4.22	<.001
Access to Healthcare	.05 (.98)	.06 (.97)	.02 (.98)	.43	.670
Neighborhood and Built Environments	.10 (.94)	.16 (.93)	−.09 (.93)	2.79	.007
Social and Community Contexts	−.02 (.99)	.22 (.93)	−.71 (.86)	10.57	<.001

Note. UFOV® = Useful Field of View; DSST = Digit Symbol Substitution Task.

Table 2.

Associations of DSST processing speed with driving mobility outcomes.

	Driving Space				Driving Exposure				Driving Difficulty in Typical Risk Settings				Driving Difficulty in High-Risk Settings			
Model Term	**β**	**SE**	***t***	***p*** ±	**β**	**SE**	***t***	***p*** ±	**β**	**SE**	***t***	***p*** ±	**β**	**SE**	***t***	***p*** ±
Baseline DSST	.12	.05	2.13	.113	−.16	.05	−3.17	.024	−.09	.04	−2.29	.151	−.05	.06	−.89	.639
*Time	−.04	.02	−1.55	.325	−.02	.02	−.88	.905	.00	.03	.08	.980	.04	.02	1.82	.234
*Race (White)	.03	.06	.53	.776	.12	.06	2.05	.213	.06	.08	.71	.765	.06	.07	.92	.639
*ES	.02	.03	.82	.579	.01	.02	.41	.917	.03	.03	.96	.674	.01	.03	.26	.945
*EAQ	−.01	.03	−.21	.895	.01	.02	.64	.905	−.02	.03	−.61	.777	−.02	.03	−.78	.699
*HCA	.01	.03	.19	.895	.02	.02	.88	.905	.07	.03	2.07	.234	.05	.03	1.71	.248
*NBE	.04	.03	1.19	.447	.01	.02	.63	.905	.13	.03	3.73	<.001	.08	.03	2.63	.048
*SCC	.04	.03	1.36	.388	.04	.02	2.22	.174	.05	.03	1.59	.394	.07	.03	2.66	.048
Change in DSST	.15	.05	3.29	.007	−.14	.04	−3.84	<.001	−.24	.06	−4.09	<.001	−.16	.05	−3.27	.010
*Race (White)	.01	.06	.22	.895	.13	.05	2.75	.058	.11	.07	1.58	.394	.06	.07	.92	.639
*ES	−.02	.02	−1.16	.247	.00	.02	.01	.989	−.02	.03	−.73	.765	−.01	.03	−.32	.945
*EAQ	.01	.03	.31	.759	.03	.02	1.56	.443	−.02	.03	−.46	.813	−.03	.03	−.91	.639
*HCA	−.04	.03	−1.31	.191	.02	.02	.75	.905	.05	.03	1.39	.469	.01	.03	.24	.945
*NBE	.03	.03	.93	.351	.03	.02	1.56	.443	.13	.04	3.55	<.001	.07	.03	2.34	.091
*SCC	.04	.03	1.64	.102	.06	.02	3.24	.016	.05	.03	1.58	.394	.07	.03	2.96	.024

Note. ES = economic stability, EAQ = educational access and quality; HCA = health care access and quality; NBE = neighborhood and built environment; SCC = social and community contexts; DSST = Digit Symbol Substitution Task

Race and each social determinant of health variable were analyzed in separate models.

"*[Variable Name]" represents a 2-way interaction term with the variable overhead.

± p-values adjusted for multiple testing using Holmes-Bonferroni procedures.

Table 3.

Associations of UFOV® processing speed with driving mobility outcomes.

	Driving Space				Driving Exposure				Driving Difficulty in Typical Risk Settings				Driving Difficulty in High-Risk Settings			
Model Term	**β**	**SE**	***t***	***p*** ±	**β**	**SE**	***t***	***p*** ±	**β**	**SE**	***t***	***p*** ±	**β**	**SE**	***t***	***p*** ±
Baseline UFOV®	.00	−.04	.02	.988	−.04	−.05	−.81	.905	.05	−.06	.90	.676	.07	−.05	1.23	.496
*Time	−.04	−.02	−2.43	.065	.02	−.02	.92	.905	.07	−.03	1.96	.245	.05	−.03	1.79	.234
*Race (White)	−.04	−.04	.94	.543	.01	−.05	.11	.954	−.04	−.07	−.59	.777	.01	−.06	.21	.945
*ES	.02	−.02	.83	.579	.00	−.02	.19	.949	.01	−.03	.35	.855	−.01	−.03	−.22	.945
*EAQ	−.01	−.02	−.30	.895	−.01	−.02	−.24	.947	−.02	−.03	−.52	.785	.04	−.03	1.29	.495
*HCA	.02	−.02	−.74	.628	−.01	−.02	−.30	.917	.00	−.03	−.08	.980	.00	−.03	.03	.979
*NBE	−.01	−.02	−.22	.895	−.01	−.02	−.45	.917	.04	−.03	1.05	.668	.02	−.03	.51	.887
*SCC	.03	−.02	1.35	.388	−.01	−.02	−.49	.905	.01	−.03	.41	.824	.00	−.03	.04	.979
Change in UFOV®	−.04	−.03	−1.10	.485	.00	−.04	−.07	.963	.08	−.06	1.27	.518	.06	−.05	1.26	.496
*Race (White)	.05	−.04	1.34	.388	.01	−.05	.14	.954	−.09	−.07	−1.29	.518	−.01	−.06	−.12	.979
*ES	−.05	−.02	−2.93	.018	.03	−.02	1.35	.573	−.02	−.03	−.57	.777	.02	−.03	−.91	.639
*EQA	.00	−.02	−.22	.895	.02	−.02	.84	.905	.01	−.03	.01	.995	.04	−.03	1.38	.445
*HCA	.00	−.02	.16	.895	.05	−.02	−2.35	.152	.03	−.03	.99	.668	.01	−.03	.41	.933
*NBE	.20	−.02	.83	.579	−.03	−.02	−1.67	.415	.02	−.03	.55	.777	−.01	−.03	−.36	.945
*SCC	.02	−.02	.94	.543	−.01	−.02	−.49	.905	−.01	−.03	−.27	.876	−.01	−.03	−.45	.919

Note. ES = economic stability, EAQ = educational access and quality; HCA = health care access and quality; NBE = neighborhood and built environment; SCC = social and community contexts; UFOV® = Useful Field of View. ®

Race and each social determinant of health variable were analyzed in separate models.

"*[Variable Name]" represents a 2-way interaction term with the variable overhead.

± p-values adjusted for multiple testing using Holmes-Bonferroni procedures.