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Cognitive Functioning Predicts Driver Safety On Road-Tests 1 and 2 Years Later

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Abstract

BACKGROUND—Our ability to predict aging related declines in driving performance from off-road assessments have clinical practice and social policy implications.

OBJECTIVES—1) To describe longitudinal changes in mean-level and evaluate rank-order stability in potential predictors of driving safety (visual sensory, motor, visual attention, and cognitive functioning) and safety errors during an 18-mile on-road-drive-test among older adults. 2) To evaluate the relative predictive power of earlier visual sensory, motor, visual attention, and cognitive functioning on future safety errors controlling for earlier driving capacity.

DESIGN—A three-year longitudinal observational study;

SETTING—A large teaching hospital in the Mid-West;

PARTICIPANTS—111 neurologically normal older adults (60 to 89 years at baseline);

MEASUREMENTS—Safety errors based on video review of a standard 18-mile on-road driving test served as the outcome measure. Comprehensive battery of tests on the predictor side included visual sensory functioning, motor functioning, cognitive functioning, and a measure of Useful Field of View.

RESULTS—Longitudinal changes in mean-levels of safety errors and cognitive functioning were small from year-to-year. Relative rank-order stability between consecutive assessments was moderate in overall safety errors, it was moderate to strong in visual attention and cognitive functioning. While prospective bivariate correlations ranged from fair to moderate between safety errors and predictors, only functioning in the cognitive domain predicted future driver performance one and two-years later in multivariate analyses.

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Conflict of Interest

The work is a product of employment and affiliation for all authors. SA, JD, EU are Co-PIs and MR is the PI.

Author Contributions:

JDD, EYU, SWA, and MR were responsible for study concept and design, with MR being the PI. MR oversaw the enrollment of subjects. NA, AMJ and JDD provided analysis of the data, with all authors helping interpret the results. All authors helped prepare the manuscript, with NA being the lead author.

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CONCLUSION—Normative aging related declines in driver performance as assessed by on-road tests emerge slowly. The findings clearly demonstrated that even in the presence conservative controls, such as previous driving ability, age, visual sensory and motor functioning, cognitive functioning predicted future driving performance on-road one and two-years later.

Keywords

neuropsychological tests; safety errors; cognitive decline; instrumented vehicle

INTRODUCTION

Epidemiological studies project large increases in the percentage of drivers over 65 years old, a cohort at increased risk for fatal crashes due to impairments of cognition, mobility and frailty.[1,2] Prevention of injuries and fatalities may require different types of interventions, including training programs to improve hazard perception and decision-making.[3] Such prevention and intervention programs that seek to preserve and extend the independence of elderly safely must be informed by evidence on both changes in performance over time and how changes with normative aging affect driver performance.[4]

As discussed in recent reviews, mounting evidence has shown motor, visual sensory functioning, visual attention, as measured by performance in Useful Field of View (UFOV), and cognitive functioning to be important to a variety of driving safety outcomes.[5,6] While self-reported crash history is considered unreliable in the US,[5,7] the relationship between two key measures of driver performance, state-recorded crash statistics and on-road-driving tests, remains unclear.[8,9] At-fault crash statistics may tap failure to meet challenging traffic situations better than safety errors made during standard on-road tests. Conversely, safety errors committed during on-road tests may be more sensitive to early declines in driver performance better, before those declines are reflected in state-recorded crash statistics.

Much of what is known about relative importance of domains of functioning to older driver safety comes from studies using crash statistics as the outcome variable.[10–14] Because crashes are relatively infrequent events, majority of studies have relied on retrospective designs with prospective studies only emerging recently.[4,11,12,15] Findings have shown that functioning in visual sensory, motor, and cognitive domains, e.g. MOMSEE, have fair to moderate effects on driver safety on a bivariate basis. In multivariate models, broad measures of cognitive functioning and UFOV performance continue to add significantly to crash prediction.[11–13] Unlike broad measures of cognitive functioning, UFOV has shown high specificity and sensitivity in distinguishing drivers with and without a crash history in a retrospective framework.[11] Further, patterns of covariation have been interpreted to indicate that UFOV reductions are the final common pathway to increased crash frequency, such that the direct effect of broad cognitive functioning on crash frequency is smaller than its indirect effect.

On-road driving tests have repeatedly distinguished between safety of elderly control drivers and drivers with neurodegenerative conditions such as Parkinson's, [16,17] and Alzheimer's disease.[7,18] On-road safety errors have also distinguished middle-aged from older drivers without neurologic disease, and broad measures of cognitive functioning have predicted elevations in safety errors after controlling for age.[19] While UFOV performance has also been useful in predicting safety error differences between controls and those with PD[17] and AD,[18] UFOV did not significantly predict concurrent safety errors in a normative sample.[19]

Evidence to date shows that it is unlikely any single test of functioning will be sensitive or specific enough to identify unsafe drivers during off-road assessments. On-road assessments will have to be combined with off-road assessments to identify unsafe drivers before unsafe behaviors lead to injury or crashes. Hence, it is critical to build a body of evidence on predictors of safety risk potential as measured by on-road tests.

The overarching goal of this study was to fill the gap in our understanding of driver safety in on-road tests in the context of a three-year prospective longitudinal design among older adults without neurodegenerative disease. Our first goal was to describe the changes in central tendency and evaluate rank-order stability on both the predictor (visual sensory, motor, visual attention, and cognitive functioning) and the outcome side (safety errors during on-road drive test). Our second goal was to evaluate relative predictive power of visual sensory, motor, visual attention, and cognitive functioning prospectively on both a bivariate and a multivariate basis on changes in driver safety as measured by on-road tests.

METHODS

Participants

111 participants between 60 and 89 years of age were recruited from the general community in a small Midwestern city through announcements in local newspapers, churches, senior centers, living facilities, and among visitors at the medical complex (e.g., family members or friends of patients). All participants held a valid state driver's license and were still driving. Drivers diagnosed with neurological and medical disorders, including brain tumor, stroke, traumatic brain injury, epilepsy, depression, dementia, sleep disorders, vestibular disorders, and alcohol or substance abuse were excluded, as were drivers taking prescription medications that may affect cognition including stimulants, antihistamines, narcotics, anxiolytics, anticonvulsants, and neuroleptics. Individuals were excluded if they had corrected visual acuity < 20/50. Participants were paid $75. Table 1 presents the demographics.

Procedure

At each assessment, participants took a battery of neurological tests that included motor, visual sensory, and neuropsychological functioning as in our previous work.[6,19] On a separate day at each assessment, the participants took an 18-mile on-road-driving test around Iowa City in an instrumented vehicle. The test included both urban and rural segments and was conducted on days when weather did not lead to poor visibility or poor road conditions. The test began after a brief acclimation period to the vehicle and a trained experimenter sat in the front passenger seat to give instructions and operate the dual controls, if needed. The vehicle, ARGOS (Automobile for Research in Ergonomics and Safety), is a midsized car with an automatic transmission and records electronic data at 10hz (e.g. steering wheel position, vehicle speed etc). Two miniature lipstick-size cameras each captured driver behavior and anterior environment.

Measures

The same battery of tests on the predictor and outcome side were administered at each assessment. The ranges from each of the tests are provided below.

Motor Functioning—Functional Reach: balance (positive distance measured in inches).[20] Get up and Go: short-range mobility (time to completion in seconds)[20] Grooved Pegboard: fine motor dexterity (time to completion in seconds).[21]

Visual Sensory Functioning—Pelli-Robson Chart: contrast sensitivity. [22] Early Treatment Diabetic Retinopathy Study chart: far visual acuity expressed as logarithm of minimum angle resolution (high scores are worse) [23] Snellen chart: near visual acuity (high scores are worse). [23]

Cognitive functioning—Judgment of Line Orientation: Visuospatial perception [24] Block Design, [25] and Complex Figure Test-Copy (CFT-Copy)[26] were administered. To tap memory, Controlled Oral Word Association (COWA) using letters C, F, and L (number of appropriate words verbalized),[27] Rey Auditory Verbal Learning Test (AVLT), anterograde verbal memory after a 30-minute delay,[26] Complex Figure Test-Recall (CFT-Recall) after a 30-minute delay,[26] and Benton Visual Retention Test[28] (BVRT) number of errors were administered. To tap visuomotor speed and executive functioning respectively, Trail Making Test Part A (TMT-A) and Part B (TMT-B) (time to completion measured in seconds in both tests) [21] were administered. Difference in time to complete TMT-A and TMT-B was used in analyses.

Visual Attention—PC-touch screen version of the UFOV test was used. [29] The subtests measuring processing speed, divided attention, and selective attention represent the threshold in milliseconds at which the individual correctly responds to 75% of the trials. The sum of four subtest scores was used.

Safety Errors—The same certified driving expert, a different person from those who conducted the road-tests, reviewed videos to scored frequency of safety errors in various categories according to the standards of Iowa Department of Transportation (September 7, 2005 version) at each assessment.[17–19] The taxonomy of 76 errors types (e.g., incomplete stop, straddles lane line) were organized into 15 categories (e.g., stop signs, lane observance). 30 of those errors were classified as serious (e.g. entering an intersection on a red light, failure to observe one way, no passing signs, straddling the center line while taking curves) and the remaining errors were considered non-serious. Serious errors are errors that would give rise to either accidents or disruptions in traffic flow had the circumstances been different. The total number of safety errors and the number of more-serious safety errors were tabulated. The driving instructor's intra-rater reliability was .95 and inter-rater reliability against another certified driving instructor on a random subsample of 30 drives was .73.

Statistical Analysis

After examining missing data patterns across three-years of data collection, we conducted univariate tests to ascertain the basic pattern of changes and stability on both the predictor and the outcome side. Tests of mean differences from baseline to year-1 and from baseline to year-2, and stability in relative rank-order between consecutive assessments were conducted at the level of individual tests tapping functioning in visual sensory, motor, visual attention, and cognitive domains. Parallel tests were conducted for both specific and overall safety errors on the outcome side. For multivariate analyses, composite scores summarizing functioning in visual sensory, motor, and cognitive domains were formed to reduce the number of predictors. Visual sensory functioning composite pooled acuity (both near and far) and contrast sensitivity measures, motor functioning composite pooled balance (functional reach), fine, and gross-motor speed (grooved peg board and get-up-and-go), cognitive functioning composite pooled all tests in the cognitive battery. High scores on all composites indicated better functioning. Those composite scores were used as predictors in multiple regressions to gauge the prospective added value of functioning in each domain to future changes in safety errors.

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RESULTS

Missing Data

Of the total 111 participants at baseline assessments, 96 returned for year-1 (attrition rate of 15%) and 78 returned for year-2 assessments (attrition rate of 30%). Mean scores at baseline of participants who did and did not return for year-2 assessments were compared with independent sample t-tests. The two groups of participants did not differ on any of the 34 tests. Hence, it is not likely that inferences from substantive analyses are biased due to systematic participant characteristics at baseline.

Describing Change & Stability

Table 2 presents the descriptive statistics for all three assessments and Spearman rank-order correlations between consecutive assessments for both predictor and outcome measures. Regarding predictors, mean difference tests indicated significant decrements in motor functioning, including Functional Reach and Get-up-go tests from baseline to both year-1 and year-2 assessments. While acuity (near and far) showed decrements only from baseline to year-2, contrast sensitivity showed decrements from baseline to both year-1 and year-2. Among individual tests in the cognitive battery, performance improved from baseline to year-1 for CFT-Recall and AVLT-Recall, and performance improved from baseline to year-2 for Block-design, CFT-Copy and CFT-Recall, AVLT, and COWA tests. In contrast, performance declined for CFT-Copy from baseline to year-1. Performance improved from baseline to year-2 for the composite cognitive functioning score and UFOV total loss scores.

Regarding outcomes, 5 out of 11 from baseline to year-1 and 3 out of 11 from baseline to year-2 showed statistically significant changes in mean level. Errors increased in railroad crossings and miscellaneous categories from baseline to year-1 and in railroad crossings and stop sign from baseline to year-2. On the other hand, errors decreased in overtaking, turns, and traffic signals categories. While decrease in errors across years was not expected, it is important to note that the significant changes in mean-level were generally small. Furthermore, errors in rail-road crossing, overtaking categories were rare events, making the significant changes less meaningful. When those less meaningful comparisons are disregarded, the number of significant differences for specific errors does not exceed chance-levels. This interpretation is strengthened when we examine changes in mean levels for composite safety error measures. Only rare, serious safety errors showed a significant decline from baseline to year-1, and neither non-serious safety errors nor overall errors showed significant changes in that time period, and the same was true for differences between baseline and year-2 assessments on composite error measures. Taken together, changes in mean level from baseline to year-1 and year-2 assessments indicated generally similar functioning on both the predictor and outcome side.

Rank-order stability between consecutive assessments was moderate to high for motor functioning, visual sensory functioning, UFOV, and most individual tests in the cognitive battery, but weak to at most moderate for safety errors. Together results show that stability in relative rank-order was moderate to strong in decontextualized, laboratory tests such as those in standard cognitive functioning batteries while stability in contextualized field tests such as safety errors was moderate.

Predicting Future Driving

The second goal of the study was to rely on multiple regressions to examine the relative utility of functioning in visual sensory, motor, visual attention, and cognitive domains for future driving performance while controlling for earlier driving performance. The relevant bivariate correlations among the predictors and the outcomes as well as standardized Beta's for significant predictors in the multivariate models are presented in Table 3.

Bivariate correlations of motor functioning with future outcome measures ranged from fair to moderate, and the corresponding correlations for functioning in visual sensory, visual attention, and cognitive domains were generally moderate (Table 3). Age and previous driving ability accounted for 28 to 30% of the variance in overall errors and 7 to 18% of the variance in serious errors in the first step in all multiple regressions. While visual sensory, motor functioning, and UFOV performance had shown significant bivariate correlations, neither remained a significant predictor in multivariate models. In contrast, cognitive functioning added uniquely to prediction in 5 out of 6 regressions. Although not shown, we also tested whether age interacted with earlier cognitive functioning to predict future driving performance. None of the two-way interaction effects between cognitive functioning and age were significant.

UFOV performance did not add significantly to prediction. The absolute value of the average intercorrelation among the predictors at baseline assessments was .34 and it was .38 at year-1.. Hence it is possible that the shared variance of UFOV with cognitive functioning composite favored the latter in the regressions. To test for this possibility, we removed the composite cognitive functioning score and re-ran the regressions. The results were not altered such that after controls for earlier driving ability, visual sensory, and motor functioning, UFOV did not predict future performance.

DISCUSSION

The overarching goal of this study was to improve our understanding of driver safety through the use of on-road tests and standardized off-road assessments in normal elderly without neurological disease in a prospective longitudinal design. We found that mean-level changes during the course of three years in safety errors were generally small, suggesting that declines in driver safety emerge gradually, confirming what we would expect based on differences in age groups in concurrent designs. A similar pattern was also true on the predictor side. While we detected small declines in visual sensory functioning and motor functioning over the course of three years, there was little change and even minor improvements consistent with practice effects among visual attention and cognitive functioning tests. While there was only a moderate degree of stability in relative rank-order in safety errors, the corresponding stability coefficients were strong for visual attention and cognitive functioning. Finally, while functioning in visual sensory, motor, visual attention and broad cognitive functioning showed fair to moderate bivariate correlations with future safety errors, only broad measures of cognitive functioning continued to predict ***changes*** in safety errors one and two-years later in the multivariate setting.

The bivariate prospective correlations we reported in this study among the predictors and outcomes were similar to those reported in the literature.[5] Our multivariate findings were also generally consistent with findings from earlier concurrent designs, in that only cognitive functioning contributed uniquely to driver performance after effects of other factors (e.g. visual sensory functioning) were controlled. Those findings contribute to the literature in two important respects. First, the correlations were all *prospective and longitudinal* in a normally aging population. Second, characteristics of this sample likely represent the general population better than studies that focus on differences between diseased groups and controls or studies that over-sample at-risk drivers. The findings clearly demonstrated that even in the presence of conservative controls, including previous driving ability, age, visual sensory and motor functioning, cognitive functioning predicted future changes in driving performance on-road one and two-years later.

One limitation is that by year-2 we had 30% participant drop-out. Although there were no differences among those who stayed in the study versus those who dropped out on the basis of their baseline characteristics, it is possible that those who dropped out experienced larger neurological decline between year-1 and year-2.

Given that meta-analytic studies have suggested UFOV has a large effect on various driving performance measures on a bivariate basis,[14] it was surprising that in our bivariate analyses, UFOV had only fair to moderate associations with future safety, and in the multivariate case it failed to emerge as a significant predictor of future safety errors. There may be several reasons for this finding.

High degree of sensitivity and specificity for UFOV has been shown in retrospective designs in which drivers with excess crashes were purposefully oversampled. Some decline in the UFOV's predictive power has been shown in prospective designs[12,15]. Further, evidence shows rates of fatal crashes among drivers older than 70 years are higher among states that require no testing.[30] Alabama is one of eight states that require no vision, knowledge or road tests to renew licenses, whereas the current Iowa sample included only those drivers who passed vision tests, raising the possibility that the maximal expected effect of UFOV performance in states such as Iowa is smaller.

A substantively more interesting possibility, however, has to do with what is captured by crash statistics versus safety errors during on-road tests in terms of driver performance. We suggested that crash statistics may tap failure to meet challenging traffic situations adequately whereas safety errors during on-road tests may tap early appearing declines in driving performance before those declines are reflected in state-recorded safety statistics. Others have noted an iceberg analogy in describing the relationship between driver behavior and safety errors. [9, 31] In this analogy, tip of the iceberg events are those rare errors that lead to crashes whereas below-the-waterline events are more common events that produce near-missès, driver induced disruptions in traffic flow, and citations. Serious errors we counted during the drive, which were rare (6 percent of total safety errors), are more similar to below-the-water-line events. Despite their rarity these errors would have given rise to near-crashes or crashes had the circumstances been different at the time they occurred. But more common non-serious safety errors, such as lane observance, lane change, and speed control, tap ability to control the vehicle. These more common, non-serious errors may be the first emerging declines in driver performance with aging. Hence, safety errors on road tests may reflect a driver's safety risk potential rather than materialized risk such as at-fault crashes. In fact, in a recent study where we studied drivers with Parkinson's disease,[32] we found that overall safety errors on-road did not predict driving cessation or crashes in multivariate analyses, but had borderline significance in predicting citations ($p=0.058$).

Recent studies indicate that the degree of convergence between on-road tests and crash statistics is fair to moderate at best.[33,34] Although crash statistics are often treated as the "gold standard" in the US of unsafe driving, this is not a uniform view and crashes have significant limitations in characterizing the safety of older drivers on the road, e.g. failure to capture accidents without police reports, or when other motorists take adequate defensive measures to avoid crashes. Evidence-based programs that seek to inform public policy such as DriveAble suggest that successful policies will combine both on-road and off-road assessments to identify older drivers that present a safety risk on the road[35].

Lack of strong convergence among measures of driver safety, including self-regulation from diminished exposure to driving cessation (a safe outcome), safety errors during on-road drive tests, citations and crash statistics, should serve as an impetus for refining empirically informed models. Given the large individual differences in the pattern of cognitive, perceptual and motor declines, specifying the nature and timing of unsafe behaviors and their associations with domains of functioning will be critical to building conceptual models and practices that promote older driver safety in a timely manner (e.g. encouraging curtailment and driving cessation) and inform public policy (e.g. whom to screen, when and how). Future studies and models will also need to invest in specifying components of off-road assessments that are most sensitive to earlier emerging declines and those that may be sensitive to later emerging declines.

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References

1. Lyman S, Ferguson SA, Braver ER, et al. Older driver involvements in police reported crashes and fatal crashes: Trends and projections. Inj Prev. 2002; 8:116–120. [PubMed: 12120829]
2. Evans L. Risks older drivers face themselves and threats they pose to other road users. Int J Epidemiol. 2000; 29:315–322. [PubMed: 10817131]
3. Horswill MS, Kemala CN, Wetton M, et al. Improving older drivers' hazard perception ability. Psychol Aging. 2010; 25:464–469. [PubMed: 20545430]
4. Bédard M, Weaver B, Darzins P, et al. Predicting driving performance in older adults: we are not there yet! Traffic Inj Prev. 2008; 9:336–341. [PubMed: 18696390]
5. Anstey KJ, Wood J, Lord S, Walker JG. Cognitive, sensory and physical factors enabling driver safety in older adults. Clin Psych Rev. 2005; 25:45–65.
6. Barrash J, Stillman A, Anderson SW, et al. Prediction of driving ability with neuropsychological tests: Demographic adjustments diminish accuracy. J Int Neuropsycol Soc. 2010; 16:679–686.
7. Iverson DJ, Gronseth G, Reger MA, et al. Practice Parameter update: Evaluation and management of driving risk in aging and in dementia (an evidence-based review): Report of the Quality Standards Subcommittee of the American Academy of Neurology. Neurology. 2010; 74:1–10.
8. Du Raedt R, Ponjaert-Kristoffersen I. Predicting at-fault car accidents of older drivers. Accid Anal Prev. 2001; 33:809–818. [PubMed: 11579983]
9. Rizzo M. Impaired driving fro m medical conditions: A 70-year-old man trying to decide if he should continue driving. JAMA. 2011:000–000.
10. Ball K, Owsley C, Sloane ME, et al. Visual attention problems as a predictor of vehicle crashes in older drivers. Invest Ophthalmol Vis Sci. 1993; 34:3110–3123. [PubMed: 8407219]
11. Owsley C, Ball K, Sloane ME, et al. Visual processing impairment and risk of motor vehicle crash among older adults. JAMA. 1998; 279:1083–1088. [PubMed: 9546567]
12. Sims RV, McGwin G, Allman RM, et al. Exploratory study of incident vehicle crashes among older drivers. J Gerontol A Biol Sci Med Sci. 2000; 55:M22–M27. [PubMed: 10719769]
13. Goode KT, Ball KK, Sloane M, et al. Useful Field of View and other neurocognitive indicators of crash risk in older adults. J of Clin Psychol Med Settings. 1998; 5:425–440.
14. Clay OJ, Wadley VG, Edwards JD, et al. Cumulative meta-analysis of the relationship between useful field of view and driving performance in older adults: Current and future implications. Optometry Vis Sci. 2005; 82:724–731.
15. Ball K, Roenker SL, Wadley VG, et al. Can high-risk odler drivers be identified through performance-based measures in a department of motor vehicles setting? J Am Geriatr Soc. 2006; 54:77–84. [PubMed: 16420201]

16. Heikkila VM, Turkka J, Korpelainen J, et al. Decreased driving ability in people with Parkinson's disease. J Neurol Neurosurg Psychiatry. 1998; 64:325–330. [PubMed: 9527142]
17. Uc EY, Rizzo M, Johnson AM, et al. Road safety in drivers with Parkinson Disease. Neurology. 2009; 73:2112–2119. [PubMed: 20018639]
18. Dawson JD, Anderson SW, Uc EY, et al. Predictors of driving safety in early Alzheimer disease. Neurology. 2009; 72:521–527. [PubMed: 19204261]
19. Dawson JD, Uc EY, Anderson SW, et al. Neuropsychological predictors of driving errors in older adults. J Am Geriatr Soc. 2010; 58:1090–1096. [PubMed: 20487082]
20. Alexander NB. Postural control in older adults. J Am Geriatr Soc. 1994; 42:93–108. [PubMed: 8277123]
21. Heaton, RK.; Grant, I.; Matthews, CG. Comprehensive Norms for an Expanded Halstead-Reitan Battery: Demographic Corrections, Research Findings, and Clinical Applications. Odessa, FL: Psychological Assessment Resources; 1991.
22. Pelli DG, Robson JG, Wilkins AJ. The design of a new letter chart for measuring contrast sensitivity. Clin Vision Sci. 1988; 2:187–199.
23. Ferris FL III, Kassoff A, Bresnick GH, et al. New visual acuity charts for clinical research. Am J Ophthalmol. 1982; 94:91–96. [PubMed: 7091289]
24. Benton, AL.; Hamsher, K.; Varney, NR., et al. Contributions to Neuropsychological Assessment. New York: Oxford University Press; 1983.
25. Wechsler, D. WAIS-III Administration and Scoring Manual. San Antonio, TX: Psychological Corporation; 1997.
26. Strauss, E.; Sherman, EMS.; Spreen, O. A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary. 3. New York: Oxford University Press; 2006.
27. Benton, AL.; Hamsher, K.; Sivan, AB. Multilingual Aphasia Examination. 3. Iowa City: AJA Associates; 1983.
28. Sivan, AB. Benton Visual Retention Test. 5. San Antonio, TX: The Psychological Corporation; 1992.
29. Edwards JD, Vance DE, Wadley VG, et al. The reliability and validity of the Useful Field of View as administered by personal computer. J Clin Exp Neuropsychol. 2005; 27:529–543. [PubMed: 16019630]
30. Levy DT, Vernick JS, Howard KA. Relationship between driver's license renewal policies and fatal crashes involving drivers 70 years or older. JAMA. 1995; 274:1026–1030. [PubMed: 7563452]
31. Heinrich, HW.; Petersen, D.; Roos, NR., et al. Industria l Accident Prevention: A Safety Management Approach. New York, NY: McGraw-Hill Companies; 1980.
32. Uc EY, Rizzo M, Johnson AM, et al. Real-life driving outcomes in Parkinson disease. Neurology. : 000–000.
33. Anstey K, Woods J, Caldwell H, et al. Comparison of self-reported crashes, state-recorded crash records and on-road driving assessment in population-based sample of drivers aged 69–95 years. Traffic Inj Prev. 2009; 10:84–90. [PubMed: 19214882]
34. Keall MD, Frith WJ. Association between older driver characteristics, on-road driving test performance, and crash liability. Traffic Inj Prev. 2004; 5:112–116. [PubMed: 15203945]
35. Dobbs, A. The development o scientifically based driving assessment and standardization procedures for evaluating medically at-risk drivers. Proceeding of Canadian Multidisciplinary Road Safety Conference XV; 2011.

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Table 1

Demographic characteristics of the sample.

		N	Mean	SD	Min	Max
Male		58				
Marital Status	Married	75				
	Divorced	7				
	Widowed	22				
	Single	7				
Education (years)		111	15.73	2.64	8	20
Age	Baseline	111	69.95	6.23	60.28	89.11
	Year-1	99	70.88	6.00	61.37	90.81
	Year-2	80	72.63	5.71	62.36	91.76
Miles driven/week	Baseline	111	161.39	193.13	14	1500
	Year-1	98	150.39	220.81	15	2000
	Year-2	80	155.19	135.13	25	800

Table 2

Descriptive statistics, paired mean-difference comparisons, and spearman rank-order correlations between consecutive assessments for all measures.

Domain	Measure	Baseline M (SD)	Year-1 M (SD)	Year-2 M (SD)	Baseline-Year1	Year-1 Year-2
		min-max	min-max	min-max	r's	r's
Motor Function	Functional Reach[a,b]	13.1 (2.7)	12.4 (3.2)	12.4 (2.6)	.42**	.39**
		6.25–20	0–21	2.5–17		
	Grooved Pegboard	87.8 (17.9)	88.1 (18.4)	88.0 (21.4)	.82**	.85**
		62–164	59.5–151	1.23–155		
	Get up & go[a,b]	8.9 (2.6)	9.7 (2.1)	9.5 (2.2)	.71**	.64**
		4.34–19	6.5–17	5.54–17.41		
Visual Sensory Function	Near Visual Acuity	.02 (.04)	.03 (.05)	.04 (.06)	.33**	.52**
		.00–.20	.00–.18	.00–.22		
	Far Visual Acuity[b]	−.07 (.12)	−.06 (.11)	−.03 (.11)	.55**	.67**
		−.28−.26	−.30−.24	−.24−.26		
	Contrast Sensitivity[a,b]	1.83 (.14)	1.75 (.15)	1.74 (.16)	.42**	.61**
		1.35–1.95	1.2–2.1	1.35–1.95		
Cognitive Function	JLO	25.6 (3.7)	25.9 (3.2)	26 (3.6)	.73**	.69**
		13–30	16–30	17–30		
	Block Design [b]	39.0 (10.5)	40.1 (9.9)	41.7 (11.1)	.77**	.74**
		12–59	20–63	12–62		
	CFT-Copy[a,b]	31.7 (3.6)	30.2 (3.8)	30.5 (3.3)	.43**	.49**
		9.5–36	17.5–36	17–36		
	CFT-Recall[a,b]	15.3 (5.8)	16.5 (5.4)	17.5 (5.3)	.51**	.69**
		1–28	5–32	5–29		
	BVRT-errors	4.8 (2.3)	4.7(2.7)	4.4 (2.9)	.39**	.47**
		0–13	0 – 16	0–12		
	TMT (Form B- Form A)	48.6 (37.4)	48.0 (35.9)	45.7 (28.3)	.45**	.56**
		6.5–271	−30 − 254	−28 − 151		
	COWA [b]	38.9 (11.4)	39.9 (11.7)	39.7 (11.2)	.78**	.80**
		9–76	14–72	9–73		

Domain	Measure	Baseline M (SD)	Year-1 M (SD)	Year-2 M (SD)	Baseline-Year1	Year-1 Year-2
		min-max	min-max	min-max	r's	r's
	AVLT[a,b]	10.1 (3.1)	10.6 (3.1)	10.4 (3.0)	.69**	.72**
		1–15	2–15	3–15		
	Overall cognitive function[b]	404.5 (45.3)	407.7 (46.3)	412.4 (47.0)	.84**	.82**
		167–485	223–515	246–508		
Visual Attention	UFOV-total score[b]	674.4 (210.5)	652 (181.9)	643.3 (216.4)	.56**	.68**
		248–1516	285–1213	195–1580		
Safety Errors	Curves	0.01 (0.1)	0.00 (0.00)	0.01 (0.1)	--	--
		0–1	0–0	0–1		
	Speed Control	3.5 (2.7)	3.5 (2.3)	4.2 (3.4)	.38**	.40**
		0–10	0–10	0–17		
	Lane change	4.9 (2.7)	4.5 (2.5)	4.8 (2.3)	.31**	.32**
		0–13	0–10	0–11		
	Lane observance	11.0 (7.7)	10.1 (6.9)	12.4 (7.5)	.34**	.29**
		0–36	0–33	1–42		
	Miscellaneous [a]	0.6 (.91)	1.0 (1.19)	1.0 (1.3)	.19	.15
		0–6	0–6	0–7		
	Overtaking[a]	0.17 (0.5)	0.0 (0.2)	0.1 (0.2)	.13	−.05
		0–3	0–1	0–1		
	Parallel Parking	0.3 (0.5)	0.3 (0.5)	0.2 (0.4)	.21+	.22+
		0–2	0–2	0–1		
	Railroad Crossing[a,b]	0.2 (0.6)	0.7 (0.5)	0.7 (0.5)	−.20+	.02
		0–2	0–1	0–1		
	Start & Pull Away Curb [b]	1.1 (0.8)	1.0 (0.8)	0.9 (0.8)	.28**	.16
		0–3	0–3	0–3		
	Stop Signs[b]	3.6 (2.0)	3.9 (1.3)	4.3 (1.1)	.31**	.04
		0–8	0–8	1–7		
	Turns[a,b]	5.5 (2.8)	4.4 (2.5)	4.7 (2.4)	.41**	.39**
		0–14	0–13	1–12		

Domain	Measure	Baseline M (SD)	Year-1 M (SD)	Year-2 M (SD)	Baseline-Year1	Year-1 Year-2
		min-max	min-max	min-max	r's	r's
	Traffic Signals[a]	2.2 (1.6)	1.6 (1.3)	2.1 (1.7)	.07	.10
		0–8	0–6	0–9		
Composite scores	Serious Errors[a]	1.9 (1.6)	1.1 (1.4)	1.6 (1.9)	.18+	.09
		0–8	0–7	0–12		
	Non-serious errors	31.3 (11.5)	29.9 (9.4)	33.9 (10.3)	.45**	.50**
		11–70	12–67	6–65		
	Overall errors	33.2 (12.3)	31.1 (10.1)	35.5 (11.3)	.45**	.45**
		12–73	12–72	7–71		

Abbrv: JLO = Judgment of Line Orientation; BVRT= Benton Visual Retention Test; CFT = Complex Figure Test; AVLT= Auditory Verbal Learning Test; COWA = Controlled Oral Word Association; UFOV = Useful Field of View

[a] statistically significant difference between baseline and year-1 assessments at $p < .05$ or better.

[b] statistically significant difference between baseline and year-2 assessments at $p < .05$ or better.

Table 3

Standardized regression coefficients examining unique predictive value of domains of functioning after adjusting for age and earlier driving ability on future overall and serious safety errors.

	Year-1				Year-2			
	Overall errors		Serious errors		Overall errors		Serious errors	
	Bivariate r	Multiv. Std. Beta	Bivariate r	Multiv. Std. Beta	Bivariate r	Multiv. Std. Beta	Bivariate r	Multiv. Std. Beta
Baseline Predictors:								
Driving Ability[a]	.49**	.39**	.29**	.17+	.52**	.41**	.34**	.22+
Age	.32**		.36**	.26*	.30**		.21*	
Miles driven/week	.10		.06		−.04		−.10	
Visual Sensory functioning	−.29**		−.22*		−.36**		−.36**	
Motor functioning	−.17		−.33**		−.33**		−.35*	
Cognitive functioning	−.34**	−.27*	−.34	−.26*	−.38**	−.22*	−.33*	
UFOV	.22*		.05		.32**		.22+	
Year-1 Predictors:								
Driving Ability[a]					.53**	.35**	.27*	
Age					.30*		.19	
Miles driven/week					−.02		−.05	
Visual Sensory functioning					−.44**		−.31*	
Motor functioning					−.40**		−.35**	
Cognitive functioning					−.43**	−.21+	−.44**	−.34**
UFOV					.41**		.26*	

Abbrv: Multiv. = Multivariate, Std = Standardized; UFOV= Useful Field of View. The overall F values for overall regressions were as follows: For overall errors at year-1 using predictors at baseline $F(6,81) = 7.28$, $p < .001$; for overall errors at year-2 using predictors at baseline $F(6,65) = 7.75$, $p < .001$ and using predictors at year-1 $F(6,65) = 7.38$, $p < .001$; for serious errors at year-1 using predictors at baseline $F(6,81) = 5.05$, $p < .001$; for serious errors at year-2 using predictors at baseline $F(6,65) = 3.97$, $p < .005$ and using predictors at year-1 $F(6,65) = 3.43$, $p < .005$.

+ $p < .10$

* $p < .05$

** $p < .01$ or better.

[a] Driving ability measures were overall safety errors or serious errors paralleling the outcome measure of focus in a given regression.