Neuropsychological Factors Associated with Useful Field of View

A thesis presented to

the faculty of

the College of Arts and Sciences of Ohio University

In partial fulfillment

of the requirements for the degree

Master of Science

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May 2014

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Neuropsychological Factors Associated with Useful Field of View

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Abstract

PATEL, D. KRUTI, M.S., May 2014, Clinical Psychology

Neuropsychological Factors Associated with Useful Field of View

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Questions about driving are common in dementia screening clinics; however, the specific cognitive impairments most associated with driving skills are unclear. Measures of Useful Field of View (UFOV), which are highly predictive of driving ability, are a cost-effective way of screening driving skills and are beginning to be used in driver's license bureaus; however, they are not commonly used in dementia screening clinics, where assessment is usually focused on diagnosis and detection of dementia. The purpose of the present study was to examine whether diagnostic measures of cognitive ability are related to driving risk, as assessed by UFOV. The first aim was to examine which cognitive constructs are most related to UFOV performance. Based on existing data on the UFOV, as well as prior studies of the cognitive domains most related to driving skill in healthy older adults, it was hypothesized that measures of cognitive flexibility, executive inhibition, visuospatial/ constructional skills and visual attention would be strongly associated with UFOV performance. The second aim was to examine whether a set of cognitive measures could be identified that accurately accounts for driving risk, as judged by clinical interpretation of UFOV scores. An important factor to consider for both study aims was the use of raw or demographically corrected scores. Whereas adjusting cognitive measures for age or other demographic factors is common practice in neuropsychological diagnostic assessments, research suggests that non-adjusted scores

are more appropriate when predicting functional abilities. Thus, for both study aims, it was hypothesized that raw scores would be more strongly related to UFOV than adjusted scores. Data for the present study were taken from an archived dataset of 114 non-demented older adults (56 - 88) who were active drivers (42% male, with an average of college level education). Results showed that, of all cognitive constructs assessed, a measure of executive function showed the strongest relationship to UFOV test performance. Consistent with study hypotheses, raw scores were more strongly related to UFOV than age-adjusted scores. Analyses of the ability of cognitive measures to predict crash risk as judged by UFOV showed that Trail Making Test B time to complete (raw score) was most related to UFOV crash risk and could possibly be used in clinical settings to screen for potential driving concerns and need for referral for driving assessment.

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Introduction

Adults aged 60 and older are the fastest growing group of drivers in the US, both in terms of annual mileage driven and the number of current drivers (Owsley & McGwin, 2010). Maintaining driving at an older age has many benefits, including giving a sense of independence and allowing an older adult to maintain mobility (Edwards, Perkins, Ross, & Reynolds, 2009). Although driving may be beneficial for older adults, older adults are overly represented in car crashes. For example, a five-year longitudinal study found adults aged 65 or older are more likely than those aged 55-64 to have state-reported car crashes (OR = 1.10, 95% CI = 1.03 - 1.17) and individuals over 75 years of age are especially more likely than those aged 55-74 (OR = 1.13, 95% CI = 1.05-1.23) to have a fatal crash (Ross, Dodson, Edwards, Ackerman, & Ball, 2011). Even after adjusting for annual mileage, adults aged 78 and older are more likely to be in an at-fault car crash compared to their car crash record from five years earlier (Ball, Roenker, Wadley, Edwards, Roth, McGwin, Raleigh, Joyce, Cissell, & Dube, 2006; Guierrier, Manivannan, &Nair, 1999). Specifically, adults aged 61 - 84 tend to be in crashes that involve failure to yield the right of way, failure to obey traffic signs and signals, and making improper turns at intersections (Guierrier et al., 1999). Concerning intersection accidents, 40% of fatalities and 60% of injuries occur drivers 64 years and older. Thus, there is a real need to understand how best to determine competency to drive in the older adult population. In the present study, we examined whether cognitive performance on clinical tasks used in dementia screening clinics are associated with driving skills, as assessed by a new driving screening test being utilized in some driver license bureaus, Useful Field of View (UFOV).

Lack of specific competency regulations for older adult driving can be costly to older adults. Driving restrictions, particularly driving cessation, based merely on age could lead to adverse consequences such as decreased physical and social activity, increased dependency, and increased depression in older adults, even when alternative transportation is available (Fonda, Wallace, & Herzog, 2001). However, the increased rate of accidents in older adults can be costly to society, because the risk of hospital stay for injuries related to car accidents increases with age (Ball et al., 2006). Currently however, there are few procedures in place to guide this important public health decision. It is commonly the responsibility of older drivers or their health care providers to judge driving competency (Myers, Ball, Kalina, Roth, &Goode, 2000; Ross et al., 2011).

Due to large variability in driver capability, drivers' license bureaus face the problem of how to differentiate between competent and incompetent older drivers. Assessing older adults' driving skills through an on-road test is both time and cost intensive and consequently is not routinely done in most states. The most common way to assess driving-relevant skills within the context of drivers' license bureaus is to test visual acuity, because driving is a highly visual task (Owsley & McGwin, 2010). Visual acuity (sharpness of vision) is often measured by using a wall chart or a visual testing machine that measures the visual acuity of both eyes individually and together (Johnson, 2005). Although driving has an obvious visual component, assessing the functional visual component needed to drive is difficult. Tests of stationary visual acuity tend to underestimate age-related deficits in vision (Ball, Owsley, Sloane, Roenker, &Bruni, 1993; Sekuler & Bennett, 2000) because they are an over-simplified view of the world, and stationary visual acuity test targets do not represent the motion-based driving environment (Owsley, Sekular, & Boldt, 1981; Owsley & McGwin, 2010). Furthermore, assessing just the visual component of driving does not address the cognitive and attentional components of driving.

One cognitive skill for which there is strong evidence of a relationship to safe driving is visual attention, defined as the ability to maintain visual concentration on a particular object (Ball, Clay, Wadley, Roth, Edwards, & Roenker, 2008; Clay, Wadley, Edwards, Roth, Roenker, & Ball, 2005; Parasuraman & Nester, 1993). Clay and colleagues (2005) conducted a meta-analysis on eight studies to examine the relationship between UFOV test performance and objective measure of retrospective or concurrent driving performance, including state-recorded accidents, on-road driving, and driving simulator performance. This meta-analysis found that after controlling for eye health, UFOV was most strongly correlated with at-fault crashes (r = 0.52), whereas visual acuity and contrast sensitivity were moderately associated with at-fault crashes (rs =0.225) (Clay et al., 2005). In fact, the types of driving errors most often made by older adults are likely due to higher order visual and attentional functions; e.g. failure to yield to signs, to yield right of way, and to turn safely (Kline, 1986), as these tasks require cognitive skills beyond visual acuity. Research shows an age-related reduction in selective attention, divided attention and a slowing in rate of visual information processing (Commodari & Guarnera, 2008; Parasuraman, & Nestor, 1991; Waller, 1991). Selective attention is the process of attending to certain stimuli, particularly when several occur simultaneously, while divided attention is the ability to split one's attention between more than one stimuli or task (Parasuraman & Nestor, 1991). Attentional costs occur in situations that call for shifting attention to aspects of the environment that are most important; there are steady declines in attentional accuracy that are evident in early adulthood (aged 19 - 23) and that steadily worsen with age (Richards, Bennet, & Sekuler, 2006). Divided-attention efficiency is known to decline in those aged 61 - 74, particularly on complex tasks (Parasuraman & Nestor, 1993). Furthermore, older adults (age 65 and older) are more likely to have impaired divided attention abilities under brief target durations and are more likely to report driving problems than adults younger than 65 (Ball, Roenker, &Bruni, 1990).

Useful Field of View (UFOV) is the visual field area where information is acquired in a brief glance without moving the head or eyes (Brenton & Phelps, 1986; Clay et al., 2005). UFOV is the visual attention window in which a driver can be quickly alerted to new stimuli. UFOV tests measure how well a person can notice, localize and identify targets in the peripheral vision field (Ball et. al., 2008). UFOV tests have shown practical and ecological validity and are a strong predictor of driving competency, specifically in the older adult population (age 60 and above), as measured by driving criteria including state-recorded accidents, on-road driving tests, and driving simulator performance (Clay et al., 2005). For example, Owsley, Ball, Sloane, Roenker and Bruni (1991) found that, of measures of UFOV, eye health, central vision, and peripheral vision, UFOV was the strongest predictor of vehicle accidents in those adults ages 57 –

83 years. UFOV accounted for 20% of the accident variance in general, and 29% of the intersection accident variance (Owsley et al., 1991). Cushman (1996) found that 82% of drivers ages 55 and older who failed a UFOV test also failed a road test and 86% of those who passed the UFOV test passed the road test. Similarly, Goode and colleagues (1998) found high levels of specificity (84.3%) and sensitivity (86.3%) for the UFOV in predicting crash involvement, as judged by previous 5 years of state driving records, in drivers ages 55 and older (Goode, Ball, Sloane, Roenker, Roth, Myers, & Owsley, 1998). Further, there is a robust relationship of UFOV test performance with driving ability across other objective measures of driving, such as on-road tests (Myers et al., 2000) and driving simulator performance (Owsley & McGwin, 2010). Because of its strong relationship to driving, drivers' license bureaus in Florida, Maryland, and California are implementing UFOV tests as a way to discern whether drivers ages 65 and older should maintain or cease their driving (Lade, 2001). In addition, the District of Columbia has changed the specific driver's license renewal procedures for drivers ages 65 and older to include shorter periods between renewal, requirement to renew in person, and passing both a vision test and a UFOV test (Highway Safety Research & Communications, 1996). Furthermore, older drivers who pass the UFOV test are offered an insurance discount from many insurance companies (DeAngelis, 2009).

Although the UFOV test is becoming adopted in the driving evaluation domain, it is not a measure routinely administered in the clinical setting. However, questions about driving are often asked in the clinical setting, especially during diagnostic evaluation for dementia. In these settings, various cognitive measures are administered for the purposes of determining whether an older adult is experiencing effects of normal aging or abnormal cognitive decline consistent with dementia. Yet clinicians who are conducting these evaluations are also often asked about functional implications of their diagnostic test findings and don't often have the UFOV test available to screen for driving safety. An understanding of what cognitive constructs are most related to driving risk, as measured by UFOV, could be useful in making recommendations for the need for further driving evaluation. Although little information is available from prior studies of UFOV to address this question, many studies have examined which neuropsychological constructs are related to other functional measures of driving, such as crash records, driving simulator performance, and on-road tests. A recent meta-analysis (Mathias & Lucas, 2009) found that measures of executive function, visual attention, visual perception, cognitive flexibility and visuoconstruction were most related to driving, as assessed by on-road test performance, simulator performance and self-reported driver problems, in nondemented drivers aged 55 and older. Whereas some of these constructs overlap with what UFOV purports to measure, no prior studies have determined if these cognitive constructs are also related to UFOV test performance.

When considering which cognitive constructs are most related to UFOV performance, it is important to consider what types of scores are available to make such a judgment. In clinical settings, the most widespread practice is to adjust test scores for age and education, in order to determine if someone's performance varies significantly from the performance of his or her peer group (Reitan & Wolfson, 2005; Silverberg & Millis, 2009). This method is most critical for diagnostic decisions; for example, to determine

whether an older adult falls outside the range of normal aging on particular cognitive tasks, which might be indicative of a diagnosis of dementia. However, comparing raw scores with the general healthy adult population norms is appropriate if one is interested in determining if a person's cognitive abilities are sufficient for the demands of universal functional tasks. Driving is a real world skill in which everyone follows the same rules, regardless of age, and where there needs to be a uniform level of cognitive ability to conduct the task. For this purpose, non-demographically corrected scores may reflect the neuropsychological status of examinees more accurately (Sherrill-Pattison et al., 2000). Further, normative comparisons that "correct" for estimated premorbid ability may actually lower the ecological validity of neuropsychological test scores for some examinees (Silverberg & Millis, 2009). Silverberg and Millis (2009) found that the absolute scores (reflecting the general healthy adult population) of neuropsychological measures were better predictors of clinical ratings of global real world functioning than the adjusted scores of the measures for individuals who were tested one year post traumatic brain injury.

In the most recent study to examine raw versus adjusted scores in the prediction of functional outcome, Barrash, Stillman, Anderson and Uc (2010) assessed the predictive accuracy of raw versus adjusted scores on cognitive measures in driving (as measured with on-road test) among 83 adults over the age of 65; approximately one third were healthy, one third had Alzheimer's disease and one third had Parkinson's disease. They found that raw neuropsychological scores accounted for a significant amount of variance in driving errors in the overall sample ($R^2 = .199, p < .005$), but demographically adjusted scores did not ($R^2 = .113, p > .10$).

Given the limited literature thus far on what neuropsychological factors are related to UFOV and the distinction of raw versus adjusted scores as predictors of driving, the present study had two aims. The first aim was to explore which measures of cognitive functioning are related to UFOV performance. The first hypothesis was that raw scores on measures of cognitive flexibility, executive inhibition,

visuospatial/constructional skills and visual attention would be more strongly correlated with UFOV performance than adjusted scores on the same constructs. For comparison to these particular cognitive domains, which were specifically selected because they are the cognitive skills most associated with driving competence (Dawson, Anderson, Uc, Dastrup, & Rizzo, 2009; Mathias and Lucas, 2009), the relation of measures of language and memory skills to UFOV performance was also examined. Past research indicates that persons with dementia have a 2.5 to 4.7 times greater risk of motor vehicle collision than population-based controls (Molner, Patel, Marshall, Man-Son-Hing and Wilson, 2006); dementia is a syndrome in which there is deterioration in memory, thinking, behavior and ability to perform everyday activities. Memory, learning capacity and language are common cognitive functions that decline in those with dementia. Including these measures allows the researcher to explore the relationship of language and memory skills to UFOV test performance. The second aim of the study was to determine whether a set of cognitive measures could be identified that together would account for a significant amount of variance in UFOV performance. It was hypothesized that a set of cognitive

measures using raw scores would account for significantly more variance than a set of cognitive measures using adjusted scores. As a corollary to this aim, we also examined whether the cognitive measure(s) identified in this second step would have clinical utility in determining driving risk, as measured by the UFOV.

Method

Data for the study came from an archived dataset. Participants in the study from which archived data were drawn were community-living adults, ages 60 and older, who participated in a larger study. For that larger study, older adults that had participated in previous studies in the Ohio University Clinical Neuropsychology Laboratory and indicated they would like to be contacted for future studies were asked to participate; other participants were recruited through newspaper advertisements (Appendix A). Participants were recruited from July 2011 to January 2013. The present study's analyses included all participants from the larger study, with exception of one participant who did not complete any of the neuropsychological measures.

There were a total of 114 participants, aged 56 – 88 (\overline{X} = 68.31, SD = 7.22) in the study. Range of education was 8 years to 27 years (\overline{X} = 16.44, SD = 3.27). 58.3% of the sample was female, 41.7% male and 93.9% were Caucasian, .9% African American and 1.7% Asian. Approximately 44.3% were still employed, whereas 55.7% were retired. 4.3% had experienced a stroke and 6.1% had experienced a myocardial infarction.

On average, participants reported beginning to drive at the age of 17 (SD = 2.49). Approximately 88.7% of the participants reported driving on a daily basis and 61.7% reported not restricting (driving less frequently, not driving at night, etc.) their driving in any way. In the present study's sample, approximately 31.2% of the older adults reported having a near-miss accident within the past year (See Appendix A for the Driving History Questionnaire and Appendix B, Table 8 for descriptive data).

Measures

Researchers administered a brief semi-structured interview (Appendix A) to collect information about past and current relevant medical and psychiatric history including age, education, vision and history of eye disease, driving history, and driving modifications. In addition, a brief questionnaire (Appendix A) was administered to gain more information on driving history.

Neuropsychological measures. Eight neuropsychological measures (Table1) were selected from the larger study based on (a) their sampling of visual processing, attention and other cognitive areas found to correlate significantly with driving performance in nondemented older adults (Dawson et al., 2009; Mathias & Lucas, 2009; Reger, Welsh, Watson, Cholerton, Baker, & Craft, 2004) and (b) widespread use in clinical practice. These measures included the Trailmaking Test A and B (TMT A and TMT B) seconds to completion; Wechsler Adult Intelligence Scale –IV (Wechsler, 2008) Block Design subtest; The Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, 1998) Line Orientation, Digit Span and Figure Copy subtests; and the Inhibition and Switching conditions of the Color-Word Interference Test of the Delis-Kaplan Executive Function System (D-KEFS) (Delis, Kaplan, & Kramer, 2001). Global impairment (used to examine potential dementia as an exclusionary criterion) was based on an RBANS composite scale score lower than the 16th percentile (sum of index scores 445 or lower; total scale of index scores 85 or lower).

TMT A was used as a measure of processing speed, whereas TMT B was used as a measure of cognitive flexibility. TMT A is highly correlated with other measures of processing speed (Sanchez-Cubillo et al., 2009; Wechsler, 2008a), whereas TMT B performance has been shown to be related to other measures of cognitive flexibility and executive functioning (Kortte, Horner, &Windham, 2002). Mitrashina and Satz (1991) reported the 1-year test-retest reliability in a group of older adults for TMT A as between .53 -.64 and TMT B as between .67 - .72.

WAIS-IV Block Design (Wechsler, 2008) is a measure visual perception and visuoconstructional skills. This subtest has a test-retest reliability of .80 over a mean of 22 days (Wechsler, 2008). Joy, Fein, Kaplan and Freedman (2001) found that the internal consistency of the block design subtest in a group of 177 healthy individuals (mean age = 68.7) was alpha = .70. This subtest shows moderate to strong correlations with other measures of visuoconstructional ability, visuoperceptual skills and visual reasoning (Wechsler, 2008).

Several subtests of the RBANS were used to measure specific cognitive skills. Digit Span (forward only), a measure of attention, has a test-retest correlation across a one-year interval of .59 (Duff et al., 2005). RBANS attention index has shown strong correlations with other, well-validated indices of attention (Wechsler Memory Scale, attention/ concentration index and the Digit Symbol subtest of WAIS-R) (Randolph, 2012). Figure Copy was used as a measure of visuoconstructional skill and has a one-year test-retest correlation of .51 in a sample of community-dwelling older adults (Duff et al., 2005). Line Orientation was used as a measure of visuospatial skills. An independent study found Line Orientation has a one-year test-retest reliability of .59 in a sample of community-dwelling older adults (Duff et al., 2005). Figure Copy and Line Orientation have shown strong correlations with other, well-validated measures of visuoconstruction and visuospatial skills (Randolph, 2012). Finally, D-KEFS Color-Word Interference condition was used as a measure of executive inhibition and the D-KEFS Switching condition was used as measure of flexibility. Inhibition and Switching conditions of DKEFS have medium to large correlations with measures of executive function that are sensitive to frontal lobe dysfunction (Delis, Kaplan, Kramer, 2001b). Detailed information on the psychometric properties of the neuropsychological measures used to test the present study's hypotheses is provided in Appendix A.

As a comparison to these cognitive measures, which were selected due to their prior relationship to driving ability, the following language and memory measures were selected for comparison purposes: D-KEFS Word Reading, RBANS Semantic Fluency, RBANS Story Recall, D-KEFS Color Naming, RBANS List Recall, and RBANS Picture Naming. D-KEFS Color Naming and Word Reading are the first two conditions of D-KEFS Color-Word Interference Test. They serve as the baseline conditions to parcel out basic naming and reading speed from the higher-level functions of verbal inhibition and switching for the other two conditions (Delis, Kaplan, Kramer, 2001b). RBANS Picture Naming and Semantic Fluency compose the language index of the RBANS test, and RBANS List Recall and Story Recall are subtests of the delayed memory index. Detailed information on the psychometric properties of the neuropsychological measures used for comparison to the cognitive measures of interest is provided in Appendix A.

Useful field of view (UFOV). UFOV; (Visual Awareness, 2009) was used as the criterion for driving ability in the present study. As noted in the introduction, UFOV is an

effective predictor of driving competency in both healthy older adults and in those with cognitive decline related to dementia. In a sample of 70 participants ages 65 years and older, the UFOV demonstrated test-retest reliability in an interval between 14 and 18 days that ranged between .72 - .88, depending on the subtest. More details on the psychometrics of the UFOV were provided above and are also provided in Appendix A.

In the present study, the Crash Risk Statement was used as the dependent variable. There are five categories of risk, with Category Level 1 being the lowest risk and Category Level 5 being the highest risk. These categories are determined based on 14 possible outcomes or combinations of scores possible based on different combinations of scores for subtests 1-3 (Visual Awareness, 2009). The UFOV Crash Risk Statement category levels are calculated by the computer program and are based on the performance of the three subtests.

Procedure

The testing sessions began by reviewing informed consent (see form in Appendix A) with the participant at the Neuropsychology Laboratory in Porter Hall, after which the background information semi-structured interview was administered. Participants were encouraged to wear their corrective lenses or glasses for the neuropsychological testing; however, basic vision screening was not conducted in the present study. Completion of the cognitive measures took approximately 2 hours. The particular order of neuropsychological measures given to each participant was the same and appears in Appendix A. Individuals received \$40.00 for their participation in the original study and

were offered clinical feedback about their overall cognitive performance relative to those of their same age and level of education.

Results

Preliminary analyses indicated non-normal distributions of the independent variables; all values of the Kolmogorov-Smirnov test of normality were p<.05. Table 2 in Appendix B shows the mean, standard deviation, range, skewness, and kurtosis *Z*-scores of each of the neuropsychological measures (raw scores); overall, the measures were not normally distributed, which is as expected given the cognitive skills being assessed. The age-adjusted scores were not normally distributed, perhaps due to the truncated scale, given the sample was overall not cognitively impaired. Adjusting the raw scores to fit a normal distribution would not allow the study to test if scores without any adjustments or transformations better predict car crash risk. Given the study's hypotheses and the relatively robust nature of the statistical analyses being conducted, the scores were used without making any transformations to have them fit a normal distribution.

The first aim of the study was to examine which measures of cognitive functioning are related to UFOV performance. It was hypothesized that raw scores on measures of cognitive flexibility, executive inhibition, visuospatial/ constructional skills, and visual attention would be more strongly correlated with UFOV performance than adjusted scores on the same constructs. In order to test this first hypothesis, we examined bivariate correlations between the UFOV Crash Risk Statement and raw and age-adjusted scores on the neuropsychological measures. Spearman correlation analyses were used because the UFOV Crash Risk Statement is rank ordered and because raw scores were skewed. It was expected that UFOV Crash Risk Statement scores would be related to Line Orientation, Figure Draw and Digit Span subtests of the RBANS; WAIS-IV Block Design subtest; D-KEFS Interference and Switching conditions of D-KEFS Color-Word Interference; and Trailmaking Test A and B. For comparison to these particular cognitive domains, which were specifically selected because they are the cognitive skills most associated with driving competence (Dawson et al., 2009), the relation of UFOV performance to measures of memory and language, which are less often related to driving in healthy older adults, were provided for comparison purposes; see Table 3 for results.

Results showed that raw scores were significantly correlated with UFOV Crash Risk Statement for ten of the fourteen neuropsychological measures (p<.01). In contrast, only two age-adjusted scores were significantly correlated with Crash Risk Statement (D-KEFS Color Naming condition and RBANS List Recall at the p<.01 level). A direct comparison of the raw versus age-adjusted correlations was done for each neuropsychological test using Fischer's Z statistics to test for the significance of the difference between correlation coefficients. Two language measures (D-KEFS Color Naming condition and RBANS Picture Naming), one attention measure (TMT A), and all the executive measures were found to have statistically different raw and age-adjusted correlations with UFOV Crash Risk Statement; consistent with our hypothesis, in all cases the raw scores were significantly more correlated with UFOV than the age-adjusted scores.

Using the raw score correlations, the results suggested that measures of executive functioning and memory were the strongest correlates with UFOV Crash Risk Statement. D-KEFS Word Reading Condition; Digit Span, Semantic Fluency, Picture Naming, Line Orientation and Figure Draw subtests of RBANS; and TMT A showed a small correlation magnitude (.1-.2 range), while RBANS Story Recall; Color Naming, Interference, and Switching conditions of the D-KEFS Color-Word Interference subtest; RBANS List Recall; WAIS-IV Block Design subtest; and TMT B showed a medium correlation magnitude (.3-.4 range).

The second aim of the study was to determine whether a set of cognitive measures could be identified that together would account for a significant amount of variance in UFOV performance. It was specifically hypothesized that a model utilizing raw scores would account for more variance than a model utilizing adjusted scores. To test this second hypothesis, two linear regression analyses were conducted. All neuropsychological tests hypothesized to be related to driving and that were significant at the p < .01 level (either raw or age-adjusted scores) were entered into two corresponding predictive models, one with raw scores and one with age-adjusted scores. The following neuropsychological measures were entered into the two models: Line Orientation, Figure Copy, and Digit Span subtests of RBANS; WAIS-IV Block Design subtest; TMT A and TMT B; and D-KEFS Switching and Interference conditions of the Color-Word Interference subtest. Variance inflation factors (VIF) measures indicated multicollinearity was not a concern for the two analyses. Regression analyses revealed that the regression model with raw sores from all seven neuropsychological measures was significantly predictive of UFOV crash risk, $R^2 = .26$, F(8, 95) = 4.13, p < .01. A parallel regression analysis with age-adjusted scores did not account for a significant proportion of the variance in UFOV crash risk, $R^2 = .10$, F(8, 95) = 1.36, p = .22.

Of the neuropsychological measures entered into the raw score model, RBANS Figure Copy and TMT B appeared to account for most of the variance in the UFOV risk statement. See Table 4 and 5 for beta weights of all measures in both regression models.

As a corollary analysis to this study aim, we examined whether the cognitive measure(s) identified in the raw score regression analysis would have clinical utility in determining driving risk, as measured by the UFOV. For this analysis, the UFOV Crash Risk Statement was converted into a binary variable, with Category Levels 1 - 2 identifying those participants at "no risk" for a car crash and Category Levels 3 - 5 identifying those participants as "at risk for a car crash." In this sample, approximately 75.7% of the sample was not considered to be at risk for a car accident.

The two measures with the highest beta weights (raw scores on RBANS Figure Copy and TMT B) from the linear regression analysis were used in the logistic regression model. A test of the full model against a constant only model was statistically significant, indicating that RBANS Figure Copy and TMT B are tests that reliably distinguished between those at risk and not at risk of a car crash, $\chi^2(2, N = 109)= 14.86$, p < .01. The TMT B odds ratio of 1.02 (p < .01) indicated that, for every one-second increase in time to complete TMT B, an older adult was 1.02 times more likely to be judged as at risk for a car crash; the RBANS Figure Copy odds ratio of .84 (p = .19) indicated that, for every1 point increase in task, an older adult is .84 times less likely to be judged as at risk for a car crash. Prediction success overall for both RBANS Figure Copy and TMT B was 80.7% (97.7% for those not at risk of a car crash, but only 17.4% for those at risk for a car crash). In other words, the specificity of these two measures (the ability to identify those not at risk of a car crash who are actually not at risk) was high at 97.7%; however, the sensitivity (the ability to correctly identify those at risk of a car crash who actually are at risk) was low at 17.4%.

Receiver operating characteristic (ROC) curves were also calculated in order to interpret sensitivity (true positive) and specificity (false-positive) rates and to determine whether cutoff scores on TMT B and RBANS Figure Copy could be determined for predicting who was at risk of a car crash. Results from this analysis found that TMT B was able to distinguish between those at risk for a car crash from those not at risk beyond chance (AUC = .78, p < .001), whereas RBANS Figure Copy was not able to distinguish those at risk for a car crash from those not at risk for a car crash from those not at risk for a car crash from those not at risk beyond chance (AUC = .78, p < .001), whereas RBANS Figure Copy was not able to distinguish those at risk for a car crash from those not at risk (AUC = .61, p = 0.12). Table 6 and Table 7 show rates of true positives and false positives associated with specific cutoff points for TMT B and RBANS Figure Copy.

Discussion

The first aim of the present study was to explore which measures of cognitive functioning would be related to UFOV performance. It was hypothesized that raw scores on measures of cognitive flexibility, executive inhibition, visuospatial/ constructional skills, and visual attention would be more strongly correlated with UFOV performance than adjusted scores on the same constructs; this hypothesis was supported by the present findings. The finding that raw scores of neuropsychological measures are more significantly correlated to a functional task is consistent with previous literature (Barrash et al. 2010; Silverberg & Millis, 2009). With regard to which specific cognitive domains were most related to UFOV performance, measures of cognitive flexibility, executive inhibition, and visuoconstruction had the largest effect size, which is consistent with previous literature on driving in older adults (Dawson et al., 2009; Mathias & Lucus, 2009). Of the measures with medium effect sizes, TMT B had the largest effect size. This is consistent with a meta-analysis conducted by Mathias and Lucas (2009), which found that TMT B was a strong predictor of driving (in nondemented older adults) when assessed through an on-road test, simulator performance, and based on self-reported driver problems. TMT B was also found to be a strong predictor of driving in a metaanalysis done using only participants with Alzheimer's disease (Dawson et al., 2009).

In addition to these hypothesized constructs being related to UFOV performance, the present study found measures of semantic fluency, memory, and language to be correlated with UFOV. There are several reasons why these measures may have been correlated with a driving task. In addition to semantic fluency being a language measure, it is a classic verbally-mediated executive function task that is highly predictive of early dementia. Monsch and colleagues (1992) found that measures of semantic category fluency demonstrate the greatest discrimination between patients with Alzheimer's disease and normal control subjects (with 100% sensitivity and 92.5% specificity). Thus, although prior driving studies have not utilized this measure as a predictor of driving ability, its relation to executive function and its sensitivity to dementia might explain its correlation with UFOV performance in the present sample. Regarding measures of memory (RBANS List Recall and Story Recall subtests), although none of the participants in the present study met criteria for a dementia or Mild Cognitive Impairment (MCI), some of the participants could have been in the early stages of MCI that was yet not detectable in the composite score used to screen for dementia, thus explaining the correlations between memory tests and UFOV performance. Previous research has shown that individuals with MCI and dementia are at a higher risk for being involved in a motor vehicle collision than age-matched cognitively normal control groups (Wadley et al., 2009) and that patients with dementia have more driving problems than non-demented controls (Frittelli et al., 2009; Rizzo et al., 2001). Thus, the present findings suggest it is important to screen for memory when examining driving safety in older adults, even if they do not meet criteria for MCI or a dementia. As for D-KEFS Word Reading condition and RBANS Picture Naming, these tests have a large time component, which might explain their significant correlation with UFOV Crash Risk Statement. However, it is notable that another timed measure (TMT A) was not highly related to UFOV Crash Risk Statement. RBANS Picture Naming and D-KEFS Word Reading are largely visual

speeded tasks, while TMT A contains a motor component, which could explain why TMT A was not as strongly correlated with the UFOV test (which has a large speed and visual component but not a complex motor component).

The second hypothesis predicted that a model utilizing raw scores would account for more variance in UFOV Crash Risk Statement than a model utilizing adjusted scores. Consistent with this hypothesis, raw scores from a set of eight neuropsychological measures accounted for a significant 26% of the variance in the UFOV crash risk statement, while in a regression model using adjusted scores for the same measures, the proportion of variance accounted for declined to a non-significant 10%. These results are consistent with those of Barrash et al. (2010) and Silverberg and Millis (2009) and provide further support for the use of raw scores when making decisions about functional capacity. In fact, this study predicted a similar amount of variance in UFOV driving performance as Barrash et al. (2010), which used similar neuropsychological measures to predict on-road driving test performance in older adults (including those with dementia). Despite study differences in sample size and composition and in measure of driving ability, a set of neuropsychological measures (raw scores) was able to predict a consistent amount of variance. Overall, the present results provide further evidence of the importance of using raw scores of neuropsychological measures when predicting driving in the older adult population.

With regard to specific constructs that emerged in the regression equation (with raw scores) as most important, the present study found measures of cognitive flexibility (TMT B) and visuoconstruction (RBANS Figure Copy) accounted for most of the variance of UFOV Crash Risk Statement. This is consistent with previous meta-analysis (Mathias et al., 2009) that found large effect sizes for measures of visuoconstruction and TMT B in the prediction of driving ability. Whereas Barrash et al. (2010) found a measure of visuoconstruction was significantly correlated with driving errors, they did not find a significant relationship between TMT B and number of driving errors. This could be explained by study differences in the outcome measure; Barrash et al. measured driving by an on-road test, whereas the present study used the Crash Risk Statement of the UFOV test. Further, as noted above, the two studies differed in sample composition, with the present study not including any individuals with diagnosed dementia or cognitive impairment, whereas Barrash et al. included participants with Alzheimer's disease and Parkinson's disease.

As a corollary to the second study aim, we also examined the ability of a set of measures to determine overall driving risk, using a binary definition of risk based on the UFOV Crash Risk Statement. Logistic regression and ROC analyses suggested that TMT B showed some clinical utility for prediction of driving risk, although overall specificity was better than sensitivity for prediction of driving risk. The base rate of participants at risk for incurring a car accident (according to the UFOV Crash Risk Statement) influence the ability of TMT B to detect who actually is at risk for a car accident. It should be kept in mind that only 24.3% of the present study's sample was determined to be at risk for incurring a car accident; this low number was reflected in a lower sensitivity rate. Including participants with a diagnosis of dementia could increase the number of participants identified to be at risk of incurring a car accident, which would likely

influence the detection rate of the TMT B (or any other cognitive test); thus, the present study's findings should not be generalized to other samples in which there is an overall higher rate of driving risk.

Limitations and Future Directions

With regard to the overall pattern of cognitive skills that were related to UFOV performance, results showed that scores from a wider variety of cognitive domains than initially predicted were related to UFOV performance. However, in the present sample, although measures that assessed more focal cognitive abilities were related to UFOV test performance, the measures that evaluated a more complex set of cognitive abilities were the most related to UFOV test performance and remained significant in the regression models, particularly TMT B. Existing literature shows TMT B taps various cognitive mechanisms (Sanchez-Cubillo, Perianez, Adrover-Roig, Rodriguez-Sanchez, Rios-Lago, Tirapu, & Barcelo, 2009) that overlap with those assessed by the UFOV subtests (visuoperception, working memory, visual scanning, speed, and task-switching ability). Thus a limitation to the present study findings is that, because TMT B is a cognitively complex task, it does not parse out the specific cognitive components of UFOV test performance. However, given the purpose for clinicians is to predict who might be at risk for being in a car accident, having a complex measure that is not only commonly used in the clinic setting to identify subtle cognitive impairments and diagnose conditions such as dementia, but is also related to driving might be clinically meaningful. Thus, it is potentially cost-effective for clinicians to administer the TMT B in a clinical setting

rather than the UFOV test, which can only be used for the purpose of detecting risk for driving.

A related limitation to the current study was the use of an archival dataset, which did not allow for selection of specific neuropsychological measures for the purpose of the present study's hypotheses. Overall, the measures and constructs used in the present study are ones that previous research has shown to be the best predictors of driving in older adults, but they were not selected specifically to assess the cognitive constructs underlying UFOV performance. The combination of measures included only accounted for 26% of the variance of UFOV Crash Risk Statement; thus, a different set of measures might be able to account for a higher percentage of the variance. Whereas the cognitive constructs chosen for this study were based on ones that previous research has shown to be the best predictors of driving in older adults, most of the tests were subtests from a screening battery (RBANS). Future studies should focus on similar constructs, but include full measures (vs. screening battery subtests), which might account for more variance in UFOV test performance. For example, the Digit Span measure on the RBANS is not a good measure of working memory, given that it only includes a forward attention span task. Further, the present study did not include a formal test of basic visual screening; participants were expected to wear or bring in their corrective lenses.

Another possible limitation is the restriction of age range in the sample. A broader age range would have been more appropriate, because prior literature has found that driving errors are significantly related to age (Barrash et al., 2010). In addition, results of the present study might not be applicable to the general older adult population because

the sample was, on average, more educated than the average older adult active driver and participants did not have clinically relevant cognitive impairment. However, the present study found that education was not significantly correlated to UFOV Crash Risk Statement (.087, p < .05). Future research should focus on using a more diverse group of older adults to determine what neuropsychological measures are related to their UFOV Crash Risk Statement. Of note, however, the sample appeared to be relatively similar in self-reported driving variables as more generalizable samples reported in national databases. For example, approximately 7.8% of the present study's sample reported incurring a motor vehicle accident in the past year; this is consistent with data from the Strategic Higher Safety Plan (2004), which reported that approximately 4% of older adult drivers (age 65 and older) incur a car accident in a year, based on state records. Further, approximately 54% of the present study's sample reported restricting their driving in some form, this is consistent with survey data from the Centers for Disease Control and Prevention, in which 57% of men and 81% of women over the age of 65 reported they avoided driving under certain conditions (CDC, 2011). Table 10 in Appendix B shows the correlations of the self-reported driving variables with UFOV Crash Risk Statement and neuropsychological measures (raw scores). Overall, the variables were not significantly related to UFOV or neuropsychological test performance, with few exceptions. The lack of significant correlations between the self-reported driving variables with UFOV Crash Risk Statement and neuropsychological measures could be explained by the nature of the self-report measure itself. Self-reports are often affected by research participants' biases and memory failures (Ross et al., 2011). For example,

research has shown that older adults with the highest number of sate-recorded crashes are typically males who tend to underreport crash involvement on self-report questionnaires (Clay et al., 2005).

These study limitations notwithstanding, the present results suggest that consideration of raw scores in clinical practice may improve the value of assessmentdriven crash risk screening. Present findings provide evidence for the utility of TMT B in dementia screening clinics as a means to assess for driving concerns and address any needs for referral for further driving assessment. This measure is easily and quickly administered and is readily available to clinicians. As can be seen in Table 6, one limiting factor for the use of TMT B in driving assessment is that high sensitivity rates also corresponded with high false positive rates. However, if TMT B is utilized only as a screening measure, higher rates of false positives in determining car crash risk would be more appropriate than missing those truly at risk. While TMT B was found to be the measure best related to UFOV test performance, it is important to note that this measure is extremely sensitive to a number of state-dependent variables such as effects of medication, caffeine, fatigue, distraction, etc. Therefore, clinicians should not rely solely on the TMT B to make any important decisions concerning the driving ability of an older adult. It is also important to consider the purpose of the driving screen (e.g. losing driver's license vs. restricting driving). If a clinician is determining whether an older adult should restrict driving, the high false positive rate of TMT B is advantageous and should be followed up with a formal assessment of driving, perhaps including the UFVO test as well as an on-road test. However, if a clinician is using TMT B as a screening

measure to determine if an older adult will lose his driver's license, the higher false positive rate would not be an advantage because of the possible loss of the benefits associated with driving. Further research with much larger and more diverse samples with different base rates of driving risk is warranted to determine the optimal cutoff points of the TMT B; however, future implementation of TMT B as a driving screening measure for older adults would allow psychologists to more easily identify those at risk for a car crash and needing further testing. Finally, it is important to emphasize that any kind of cognitive test score cannot be used in isolation to determine such a complex behavior such as driving crash risk. Driving depends on an interplay between various cognitive abilities, neurobehavioral functioning, physical limitations and environmental factors and requires more complex assessment, including perhaps more time and cost intensive methods, should screening suggest a risk.
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Outline of Assessment Procedures for the Larger Driving Study

Measures in Larger Driving Study	Domains Assessing
Background Information Semi-Structured	Demographics and medical
Interview*	history information
Driving History Questionnaire	
Repeatable Battery for the Assessment of	Visuospatial/constructional (Lin
Neuropsychological Status (RBANS)*	Orientation Subtest and Figure
	Copy Subtest) &
	attention/concentration (Digit
	Span Subtest)
Trail Making Test A & B*	Speed of processing (part A) &
-	cognitive flexibility (part B)
Benton Visual Retention Test	
Matrix Reasoning	
Wechsler Adult Intelligence Scale (WAIS-IV)	Visual perception/ visual-
Block Design*	constructional
Delis-Kaplan Executive Function System (D-	Executive inhibition function
KEFS) Color-Word Interference Test*	(Color-Word Interference Test;
,	Inhibition and Switching
	conditions)
	conditions)
Hooper Visual Organization Test	conditions)
Hooper Visual Organization Test Useful Field of View*	Driving ability (Crash Risk

Note. *Measures that were used in the study.

Descriptive Statistics for Raw and Age-Adjusted Scores

	Ν	Raw Mean (SD)	Raw Score Range	Kurtosis Z-Score (Raw)	Skewness Z-Score (Raw)	Age- Adjusted Mean (SD)	Age- Adjusted Score Range
D-KEFS Word	112	24.87 (9.14)	16 - 88	53.00	18.94	10.46 (2.71)	1-15
RBANS Semantic Fluency	114	21.17 (4.82)	11 - 36	1.27	1.59	12.37 (2.69)	6 - 18
RBANS Story Recall	114	9.54 (1.80)	2 - 12	3.87	- 4.16	11.96 (2.22)	5 - 16
RBANS Picture Naming	114	9.82 (.45)	8 - 10	12.66	- 10.97	9.77 (.90)	6 - 11
D-KEFS Color	113	33.93 (9.10)	20 - 75	9.53	7.42	9.93 (3.23)	1 - 15
RBANS List Recall	114	6.27 (2.05)	2 - 10	1.45	40	11.78 (2.26)	7 - 17
RBANS Line Orientation	114	17.57 (2.52)	8 - 20	4.09	- 5.83	11.58 (2.27)	5 - 15
RBANS Figure Draw	113	18.26 (1.85)	12 - 20	3.96	-6.02	10.05 (2.19)	4 - 13
WAIS-IV Block Design	114	37.65 (10.43)	12 - 59	- 1.80	.22	11.32 (2.64)	5 - 18
RBANS Digit Span	114	10.79 (2.18)	6 - 16	20	.27	9.85 (2.20)	4 - 15
TMT A	111	36.45 (13.28)	15 - 91	5.30	5.53	10.46 (2.98)	3 - 18
D-KEFS Interference	112	61.22 (15.93)	18 - 106	1.97	.71	11.84 (2.56)	5 - 19
D-KEFS Switch	112	68.13 (19.84)	25 - 135	4.10	5.00	11.63 (2.65)	2 - 18
TMT B	113	82.41 (45.43)	41 - 358	37.61	16.36	11.00 (2.55)	2 - 16

Note. D-KEFS = Delis–Kaplan Executive Function System; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; TMT = Trailmaking Test; WAIS-IV = Wechsler Adult Intelligence Scale.

Correlations of Raw vs. Age-Adjusted Scores from Neuropsychological Measures with UFOV Crash Risk Statement

		UFOV Risk				
		Raw Spearman's Rho	Age- Adjusted Spearman's Rho	Fischer's Z	p (1-tailed)	
	D-KEFS Word	0.190*	-0.095	2.14	0.02	
Language and	RBANS Semantic Fluency	-0.295**	-0.155	-1.1	0.14	
Memory Predictors	RBANS Story Recall	-0.334**	-0.229*	-0.85	0.20	
	D-KEFS Color	0.358**	0.307**	0.43	0.33	
	RBANS List Recall	403**	295**	-0.92	0.18	
	RBANS Picture Naming	25**	.01	1.97	0.02	
Visuo-	RBANS Line Orientation	271**	200*	-0.56	0.29	
Spatial Predictors	RBANS Figure Draw	231*	100	-1.01	0.16	
	WAIS-IV Block Design	430**	242*	-1.59	0.06	
Attention/ Speed	RBANS Digit Span	129	107	-0.17	0.43	
Predictors	TMT A	.230*	086	10.06	< .01	
	D-KEFS Interference	.341**	181	4.01	< .01	
Executive Predictors	D-KEFS Switch	.344**	236*	4.46	< .01	
	TMT B	.453**	221*	5.31	< .01	

Note. D-KEFS = Delis–Kaplan Executive Function System; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; TMT = Trailmaking Test; WAIS-IV = Wechsler Adult Intelligence Scale. * Indicates significance at p < .05 level and ** indicates significance at p < .01 level.

Beta Weights of Neuropsychological Measures in Raw Scores Regression Model

	Unstandardized		Standardized	Т	Sig.
	Coefficie	ents	Coefficients		
	В	Std. Error	Beta		
(Constant)	4.06	1.37		2.90	< .01
RBANS	< .01	.05	< .01	.06	.95
Line					
Orientation					
RBANS	13	.06	21	-2.12	.04
Figure					
Draw					
WAIS-IV	02	.01	19	- 1.73	.09
Block					
Design					
RBANS	06	.05	11	-1.14	.26
Digit Span					
TMT A	< .01	< .01	< .01	<.01	.99
D-KEFS	< .01	< .01	.02	.13	.89
Interference					
D-KEFS	.01	< .01	.21	1.61	.11
Switch					
TMT B	< .01	< .01	.21	2.01	.05

Note. D-KEFS = Delis–Kaplan Executive Function System; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; TMT = Trailmaking Test; WAIS-IV = Wechsler Adult Intelligence Scale.

Beta	Weights	of N	Veuropsych	ological	Measures	in A	Age-Adiusted	Scores	Regression	Model
Detta	,, eignis	91	eur opsyen	orogreat	11100050105	111 1.	180 110/05/00	Scores	negi ession .	1100001

		Unstandard	ized	Standardized	Т	Sig.
		Coefficier	nts	Coefficients		
		В	Std. Error	Beta		
(Constant)	4.37		.98		4.45	< .01
RBANS	02		.06	05	40	.69
Line						
Orientation						
RBANS	04		.06	08	77	.45
Figure						
Draw						
WAIS-IV	05		.05	12	- 1.04	.30
Block						
Design						
RBANS	05		.05	10	93	.36
Digit Span						
TMT A	.04		.04	.10	.88	.38
D-KEFS	02		.05	05	50	.62
Interference						
D-KEFS	09		.06	20	-1.47	.15
Switch						
TMT B	05		.05	11	97	.33

Note. D-KEFS = Delis–Kaplan Executive Function System; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; TMT = Trailmaking Test; WAIS-IV = Wechsler Adult Intelligence Scale.

TMT B Cutoff Scores Sensitivity Rate False Positive Rate 100% 63.2% 60 or more 90% 54% 64 or more 66 or more 80% 52.9% 70% 71 or more 43.7% 28.7% 79 or more 60% 50% 12.6% 94 or more 106 or more 40% 5.7%

Cutoff Points of TMT B and Sensitivity and False Positive Rates

Note. TMT = Trailmaking Test.

Table 7

Cutoff Points of RBANS Figure Draw and Sensitivity and False Positive Rates

RBANS Figure Draw Cutoff Scores	Sensitivity Rate	False Positive Rate
21 or less	100%	0%
20 or less	88%	12%
19 or less	50%	50%
18 or less	33%	67%
17 or less	25%	75%
16 or less	17%	83%
15 or less	8%	92%
14 or less	4%	96%
13 or less	0%	100%

Note. RBANS = Repeatable Battery for the Assessment of Neuropsychological Status.

Appendix A: Detailed Psychometric Properties of Study Measures Driving Ability

UFOV; (Visual Awareness, 2009) was used as the criterion for driving ability in this study. UFOV is a computer-based test that is administered according to the Users' Guide Version 6.14 (Visual Awareness, 2009). In a sample of 70 participants aged 65 years and older, the UFOV demonstrated test-retest reliability in an interval between 14 and 18 days that ranged between .72 - .88, depending on subtest. Specifically, subtest 1 had the lowest reliability, followed by subtest 3 then subtest 2 (Visual Awareness, 2008). As reviewed above, there are significant data suggesting that UFOV is highly predictive of driving safety in older adults. High levels of specificity (84.3%) and sensitivity (86.3%) are found at the standard cutoff score of 40% reduction of UFOV in older adults aged 55 years and older (Goode et al. 1998). Goode and colleagues (1998) found that UFOV at this cutoff was the measure most strongly related to crash involvement over the previous 5 years based on state records, out of a number of neuropsychological measures: Trail Making Test A and B, (Spreen and Strauss, 1991), Mattis Organic Mental Syndrome Screening Examination (Mattis, 1976), Wechsler Memory Scale – Visual Reproduction Subtest (Wechsler, 1945) and Rey-Osterrieth Complex Figure Test (Lezak, 1983). Scores from the three UFOV subtests were combined to yield a score between 0 and 90, which represented the percentage reduction of UFOV (Goode et al., 1998).

Ball et al. (1993) found that 40% or greater reduction in UFOV size yielded the best cutoff for separating high risk versus low risk drivers. The UFOV manual (Visual

Awareness, 2009) described a study comparing the older versions of this computer test that measured percentage reduction with the newer PC version of the test that measures speed in msec. Study results showed durations longer than 100 msec. on Subtest 2 and longer than 350 msec. on Subtest 3 resulted in specificity of .91 and sensitivity of .91. In fact, 91% of those that passed the original version passed the new PC version; of those that failed the older version, 91% also failed the new PC version (Visual Awareness, 2009). The study assessed UFOV by the Crash Risk Statement. There are five categories of risk, with Category Level 1 being the lowest risk and Category Level 5 being the high risk. These categories are determined based on 14 possible outcomes or combinations of scores possible based on different combinations of scores for subtests 1-3 (Visual Awareness, 2009).

Overall Cognitive Impairment

The Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, 1998) was administered to all participants. The RBANS is a brief and comprehensive cognitive screening test commonly used in dementia clinics. This instrument can be used on those 20-89 years old and is composed of 12 subtests assessing the domains of attention, language, immediate and delayed memory, visuospatial/ constructional abilities (Randolph, 1998; Randolph, Tierney, Mohr, Chase, 1998). The 12 subtests include: list learning, story memory, figure copy, line orientation, picture naming, semantic fluency, digit span, coding, list learning free recall, list learning recognition, story memory free recall, and figure free recall. The RBANS total score correlates highly with more extensive assessments of cognitive impairment and has been

shown to have good sensitivity and specificity for dementia detection and everyday functioning in those with neurological disorders (Duff, Clark, O' Bryant, Mold, Schiffer, Sutker, 2008). The RBANS total score was used to exclude any participant from the archived data that showed overall cognitive impairment.

Specific Cognitive Predictors

Visuospatial. Line Orientation is a subtest of the RBANS; the total score will be used as a potential visuospatial predictor of UFOV performance because drivers' awareness and understanding of objects in space is related to safe driving (Renney, 1994). The Line Orientation subtest requires participants to judge the orientation and angle of two lines and identify and match from a choice of 13 equal numbered lines radiating from a single origin and forming a half-circular fan-like pattern. The participant is given 20 seconds to identify each pair of lines in 10 trials. One point is awarded for each correctly identified line, with a total of 20 points possible for the entire subtest. A test-retest (248 – 640 days; mean = 379 days) reliability of .59 for the Line Orientation subtest was recorded in an independent study with a sample of community-dwelling older adults (Duff et al., 2005). The RBANS visuospatial/constructional index (which consists of Figure Copy and Line Orientation) has a test-retest reliability of .85 in a group of 60-69 year olds and a standard error of measurement of 6.00 (Randolph, 1998). Raw scores were the total number of correct responses. Age-adjusted scores were determined by data reported in Duff, Patton, Schoenber, Mold, Scott and Adams (2003).

Visuoconstructional. Figure Copy is another subtest of the RBANS; in this subtest of the RBANS, the participant is presented with the Figure Copy stimulus page

from the Stimulus Booklet and asked to copy the figure exactly. They are not permitted to move the booklet but may move the paper they are drawing upon. Participants are told the score is based on exactness of the copy rather than the speed of which it takes them to complete the task. However, they are limited to 4 minutes to complete their drawing. Scoring is based on exactness of drawing and correct placement for 10 aspects of the figure (total score ranges from 0-20). Figure copy interscorer agreement was .85 across 3 trained scorers, who each scored 20 random figure copy/recall subtests (Randolph, 1998). Duff et al. (2005) conducted a study with a large community dwelling elderly sample across a one-year retest interval and found the test-retest correlation was .51, with a practice effect of -.12. For the analyses, raw scores were determined by total number of correct responses and age-adjusted scores were determined by reference to Duff et al. (2003).

Block Design is a subtest of the Wechsler Adult Intelligence Scale -IV (Wechsler, 2008) and measures visual perception and visuoconstructional skills. The test requires participants to use blocks to reproduce a picture of a model. This subtest has a test-retest reliability over a mean of 22 days of .80 (Wechsler, 2008). Joy, Fein, Kaplan and Freedman (2001) found that the internal consistency of the block design subtest in a group of 177 healthy individuals (mean age = 68.7) was alpha = .70. This subtest shows moderate to strong correlations with other measures of visuoconstructional ability, visuoperceptual skills and visual reasoning (Wechsler, 2008). Block Design demonstrated good ecological validity by being moderately correlated with measures of everyday visuospatial skills (Groth-Marnat & Teal, 2000). Block Design has been shown to be a

good predictor of driving difficulties in older adults (Mathias & Lucas, 2009). Both raw scores and age-adjusted scores of this test were used in the analyses. Raw scores were determined by total number of correct responses and age-adjusted scores were determined using the WAIS-IV (Wechsler, 2008) administration and scoring manual.

Attention. Digit Span subtest is part of the attention index in the RBANS. This subtest requires participants to repeat back a string of letters in the same order they were read. Numbers are read to the participant at a rate of 1 per second and the second string of each item is only read if the first string was failed. Responses are recorded verbatim; 2 points are awarded if the first string of the item is correct. If the second item of the string is administered, a score of 1 point is awarded to a correct response or 0 points if it is incorrect. Total score ranges from 0-16. The RBANS attention index is highly correlated with the Wechsler Memory Scale-Revised attention/concentration index (r = .82). Duff et al. (2005) found the test-retest correlation across a one-year retest interval was .50 with a practice effect of -.09. For the analyses, raw scores were determined by total number of correct responses and age-adjusted scores were determined by reference to Duff et al. (2003).

Speed of processing. Trail Making Test Part A requires the participant to draw lines to sequentially connect 25 encircled numbers that are written across a page in a random fashion. They are instructed to draw the lines as quickly as possible. Part B requires the participant to draw connecting lines, alternating between numbers (1-13) and letters (A-L). Scores are obtained by amount of time to complete task and number of errors made. Trail Making Test A is correlated highly with visual search and speed (Crowe, 1998).Matarazzo et al. (1974) reported the test-retest reliability for a test interval of 12 weeks had reliability coefficients of .46 for part. Dikmen et al. (1999) examined 384 neurologically stable adults (age 15-83 years; M = 34.2) who were retested 11 months after the initial test session; coefficients were adequate for Part A (.79) (Strauss, Sherman and Spreen, 2006). Both raw scores and age - adjusted scores will be used in the analyses. Raw scores were the time taken to complete the task and age-adjusted scores were determined by referencing the normative data gathered by Ivnik, Malec, Smith, Tangalos and Peterson (1996).

Cognitive flexibility. Trail Making Test B is a test of executive function, specifically, cognitive flexibility (Lezak, Howieson, Bigler, Tranel, 2012, pg. 422). Trail Making Test B (TMT B) on its own has been more strongly associated with executive function, specifically, task-switching or cognitive flexibility (Perianez, Rios-Labo, Rodriguez-Sanchez, Adrover-Roig, Sanchez-Cubillo, Crespo-Facorro, Quemada & Barcelo, 2007). The present study categorized TMT B as a test of executive function because it is a task that measures a variety of abilities (attention, working memory, speed, planning, inhibition, etc.); cognitive flexibility is an umbrella term that best captures the various abilities this task measures. TMT B is associated with driving errors, crash history (Ball et al., 2006) and performance on road tests (Zook, et al., 2009). Matarazzo et al. (1974) reported the test-retest reliability for a test interval of 12 weeks had reliability coefficients of. 44 for part B. Dikmen et al. (1999) examined 384 neurologically stable adults (age 15-83 years; M = 34.2) who were retested 11 months after the initial test session; coefficients were high for part B (.89) (Strauss, Sherman and Spreen, 2006). Both raw scores and age - adjusted scores were used in the analyses. Raw scores were the time taken to complete the task and age-adjusted scores were determined by referencing the normative data gathered by Ivnik, Malec, Smith, Tangalos and Peterson (1996).

Executive inhibition. The Color-Word Interference Test (WCIT) is a subtest of the Delis-Kaplan Executive Function System (D-KEFS) (Lezak, Howieson, Bigler, Tranel, 2012, pg. 706) and is designed to measure the executive inhibition function with an added switching component. This subtest is modeled after the classic Stroop colorword test (1935) procedure, which is commonly used to elicit mental stress. Collet, Petit, Priez and Dittmar (2005) investigated male drivers' aged 22 - 48 (mean age = 30.4) performance on an on-road test. The driving test included a critical crash avoidance situation and physiological arousal was measured (via skin conductance) before and during the driving test. Before driving, the participants were divided into four groups of resistance to stress based on their performance on the Stroop task (very low, low, high, very high). Results found those that performed the least well on the driving test also performed the least well on the Stroop test. The proportion of participants who passed the driving test was significantly different from those that failed it ($X^2 = 12.80$, p = .045). The study concluded Stroop test performance and physiological arousal are determining factors of driving situations that have a time-constraint component (Collett et al., 2005).

The D-KEFS includes two naming conditions, a traditional interference condition and a switching condition. In the first condition, Color Naming, participants are presented with a page with patches of color and are asked to name each color as quickly as can. The

second condition, Word Reading, evaluates the participant's ability to read words denoting colors printed in black ink as quickly a possible. These first two conditions provides a baseline measure for parceling out basic naming and reading skills from the higher-level functions of verbal inhibition and switching (conditions 3 and 4)(Delis, Kaplan, & Kramer, 2001b). In the interference condition (3), the participants are presented with words of colors printed in different ink color and are to name the ink color of each word and not to read the word. In the switching condition, the participant is presented with a page similar to the interference condition but some words are in a black box. Participants are to follow the same rule as in the interference condition, however, when the word is in a box, they are to read the word and not name the color of the ink. Based on a sample size of 101 across all age groups for an average of 25 days, the testretest correlation ranged from .62 - .76 for the Interference subtest (Delis, Kaplan, Kramer, 2001; Strauss, Sherman, Spreen, 2006, pg. 447). In a study with 72 communitydwelling older adults, D-KEFS Color-Word Interference Test was the most predictive (from a number of executive function assessments) of individuals' performance on daily living activities in a sample of community-dwelling older adults (Jefferson, Paul, Ozonoff & Cohen, 2006). The study used raw scores and age adjusted scores in analyses. Raw scores were determined by the time taken to complete the Interference subtest and age-adjusted scores were determined by reference to the D-KEFS Examiner's Manual (Delis, Kaplan, & Kramer, 2001).

Language. The Picture Naming and Semantic Fluency subtests compose the language index of the RBANS. In the Picture Naming subtest, the participant is presented

with a series of pictured objects and is asked to name each picture. A semantic cue is provided if an object is obviously misperceived (Randolph, 1998a). One point is awarded for each correct response; total score range for the subtest is 0 - 10. In the Semantic Fluency subtest, the participant is given one minute to name as many exemplars as possible from a given semantic category (Form A has fruits and vegetables, Form B has animals found in the zoo). Any fruit or vegetable is scored as correct/ or all animals that could conceivably be in a zoo are scored as correct. The total score range for this subtest is 0 - 40. The language index is strongly associated with the following measures of language/achievement: Wide Range Achievement test (WRAT-3; Jastak & Wilkinson, 1993), Reading Scaled Score (r = .21), Boston Naming Test, total score (r = .75) and Controlled Oral Word Association test (COWA; Spreen & Benton, 1977), total score (r = .59) (Randolph, 1998a).

Delayed memory. In the subtest List Recall, the participant is asked to recall the list of 10 words learned in the List Learning subtest. Participants are not given feedback as to whether the words are correct or not. Each of the participant's responses are recorded verbatim and 1 point is awarded for each correctly recalled words. The sum of each correct item is used to obtain the total score; the total score ranges from 0 - 10 (Randolph, 1998a). List Recall measure the delayed free recall for unrelated verbal information. In the Story Recall subtest, the participant is asked to recall the story they learned earlier. The participant's response is recorded verbatim and one point is awarded for each correctly recalled bold, italic word or alternative. The sum of the scores for each item is used to obtain the total score; total score range is 0 - 12 (Randolph, 1998a). Story

Recall measures delayed free recall for conceptually related verbal information.

Reliability coefficients of Story Recall subtest and the Delayed Memory index in a group of 60-69 year olds was r = .72 and .85, respectively. The reliability coefficients for this subtest and index in a group of 70-79 year olds and 80-89 year olds was r = .72, .83 and .72 and .81, respectively. The test-retest reliability coefficients for the List Recall subtest, Story Recall subtest and the Delayed Memory index was r = .66, .48 and .70, respectively (Randolph, 1998a).

Speed and naming. In the first condition of D-KEFS Color-Word Interference Test, Color Naming, participants are presented with a page with patches of color and are asked to name each color as quickly as can. Participants are instructed to name the targets for each condition as quickly as they can without making mistakes. In a group of 50-89 year olds, Condition1: Color Naming had a test-retest reliability coefficient of r = .56(Delis, Kaplan, & Kramer, 2001). This condition has a correlation r = .62 with the second condition (word reading), r = .52 with the interference condition and r = .42 with the interference/switching condition (Delis, Kaplan, & Kramer, 2001).

Speed and reading. The second condition of D-KEFS Color-Word Interference Test, Word Reading, evaluates the participant's ability to read words denoting colors printed in black ink as quickly a possible. In a group of 50 - 89 year olds, Condition 2: Word Reading, had a test-retest reliability coefficient of r = .56 (Delis, Kaplan, & Kramer, 2001). This condition has a correlation of r = 47 with the interference condition and r = .41 with the interference/switching condition. Again, this condition serves as a baseline measure for parceling out basic reading speed from performance on Condition 4 (where reading responses are required for half the items. This condition also serves as a separate measure of fundamental linguistic skill of speed of reading; an above average score on this condition indicates the participant's ability to read high-frequency words quickly is a relative strength (Delis, Kaplan, & Kramer, 2001b).

Copies of Study Measures Driving history questionnaire.

Driving History Questionnaire

1. Approximately how old were you when you got your driver's license? 2. Apart from a standard driver's license, did you ever hold any other class of license? No_____ Yes If Yes, what kind? ______ (e.g., bus, truck, tractor-trailer, etc.) Using a scale from 0 to 4 answer the following questions 3 through 5 below (0 – never 1 – rarely 2 - occasionally 3 – often 4 - very often) 3. Over the past 2 years, how often have you driven on the following types of roads? ____ residential streets ____ main city streets _____ rural roads _____ freeways (e.g., e.g., I-70; 270) ____ highways (e.g.,33, 52,32) 4. Over the past 2 years, how often have you driven in new unfamiliar areas? 5. Over the past 2 years, how often have you driven on one-way trips that took 2 hours or longer? 6. Have you taken any driving courses? ____ No ____ Yes If so, about how long ago? _____ 7. In the past year, have you had any of these problems when driving? ____ No ___ Yes Accidents involving another vehicle? ____ No ___ Yes Near misses (almost an accident)? Backing into things besides other cars? ____ No ___ Yes Getting lost? ____ No___ Yes Traffic violations with loss of demerit

____ No ____Yes

Office of Research Compliance, Rev. 04/2009

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points?

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Page 3 of 3

Interview form. INTERVIEW FORM (2011)
ID NUMBER DATE
(ID is first initial Mom's name, first initial Dad's name, MO of birth, DA of birth (numerical)
Sex M F Age Race/ethnic background Date of birth:
How many years of education have you completed?
Are you currently employed? If YES, what is your job?
If NO, are you retired? What was your job? How long since you retired?
Have you ever been diagnosed with a learning disability? If so, what type?
Have you ever lost consciousness due to a blow to the head or other head injury? Y $$ N $$
If yes, for how long did you lose consciousness? Did you see a doctor?
Were you hospitalized? What was your diagnosis, if any? Did you have any form of treatment?
Have you ever had: (if yes to any, get details about when and what, treatment) Seizures? Y N Brain tumor? Y N (details here:) Stroke? Y N (details here:) Heart attack? Y N (details here:) Do you have any other neurological/medical problems? (please list, and list when diagnosed)

What current medications do you take? (please be specific with name, or at least descriptive by what the medication is supposed to treat – antihypertensive medication, for example) (write none for none)

Have you ever seen a mental health professional (psychiatrist, psychologist, counselor?) Y ${\sf N}$

If yes, when (including currently) _____ For what diagnosis(es)?

Do you currently drive? Y N

If no, when did you last drive? (date) _

If yes, how often do you drive? daily weekly monthly less than monthly

Do you restrict your own driving compared to when you were younger? If yes, how?

Useful field of view subtests.

Subtest One



Figure 1.1. Viewing target object.



Figure 1.2. Picking which object was in the box.

Subtest Two



Figure 2.1. Viewing both object in the box and outside the box.



Figure 2.2. Identifying which object was in the box.

Figure 2.3. Identifying on which spoke the peripheral object was located.

Subtest Three

Figure 3.1. Viewing both object in the box and outside the box.

Figure 3.2. Identifying which object was in the box.

Figure 3.3. Identifying on which spoke the peripheral object was located.

Informed consent

APPROVED

MAR 1 5 2012

Ohio University Consent Form

OHIO UNIVERSITY

Title of Research: Neuropsychological Predictors of Driving Hazard Perception in Older Adults (Session I)

Researchers: Julie Suhr, Ph.D., & Deb McAvoy, Ph.D.

You are being asked to participate in research. For you to be able to decide whether you want to participate in this project, you should understand what the project is about, as well as the possible risks and benefits in order to make an informed decision. This process is known as ir formed consent. This form describes the purpose, procedures, possible benefits, and risks. It also explains how your personal information will be used and protected. Once you have read this form and your questions about the study are answered, you will be asked to sign it. This will allow your participation in this study. You should receive a copy of this document to take with you.

Explanation of Study

This study is being done because we are interested in learning more about how changes in cognitive skills associated with aging are related to challenging driving situations. If you agree to participate, you will be asked to complete several measures of thinking and memory skills. Some of these are paper and pencil puzzle type tasks and some are computerized. Then you will take a short stroll over to another building, in which you will get to participate in a driving situation using a simulator. You will be seated in the simulator and have eye tracking equipment placed upon you. Then the controls of the simulator will be explained to you and you will complete a brief training protocol to help you become familiar with the simulator and how it vorks. Then you will experience three brief driving situations in which you will be exposed to various hazardous driving situations. We will measure your reaction to those hazards (your eye tracking towards them, and your driving respor se such as braking, etc.). Between each driving situation, you can take a brief break.

Your participation in the study will last about 4 hours.

Risks and Discomforts

Risks or discomforts that you might experience are anxiety about your performance on either the cognitive or driving tests, and possible motion sickness during the driving simulator. You will be provided with clinical feedback about your performance on the cognitive tests by Dr. Suhr, a licensed psychologist, which should help to minimize any anxiety you experience about the cognitive tests. The driving simulator tests were specifically designed to be challenging and to increase likelihood of driving errors or crashes and are NQT

clinical evaluation of your driving skills.

With regard to your potential for driving sickness, the training protocol described above is designed to acclimate you to the driving scenario and has been shown by Dr. McAvoy to minimize your risk for motion sickness; however, if you experience such symptoms you can take a rest or discontinue participation at any time.

<u>Benefits</u>

This study is important to science/society because results could provide a better understanding of the kinds of cognitive changes that are related to changes in driving skills in aging, and potentially lead to better interventions to minimize these risks.

Individually, you may benefit from receipt of feedback about your own cognitive changes.

Confidentiality and Records

Your study information will be kept confidential by creating a unique identifying code for your data. This will consist of: the first letter of your mother's first name, the first letter of your father's first name, the month of your birth, and the actual date of your birth (NOT the year). For example, a participant whose mother's name is Mary and whose father's name was Bill, and whose birthday was on June 5th, would have the code MB0605. Thus, no code key will be kept and the number will not allow you to be identified by your code. In addition, all data from the study will be maintained in locked files or on password protected computers, accessible only to the Study Directors and their research assistants.

Additionally, while every effort will be made to leep your study-related information confidential, there may be circumstances where this information must be shared with:

- * Federal agencies, for example the Office of Human Research Protections, whose responsibility is to protect human subjects in research:
- * Representatives of Ohio University (OU), including the Institutional Review Board, a committee that oversees the research at OU;

Compensation

As compensation for your time/effort, you will receive 40 dollars. If you discontinue the study early, your compensation will be prorated (i.e., you will receive 10 dollars for every completed hour of the 4-hour study).

Please note that, because University funds will be used to compensate you, your name and address will need to be provided to the Finance Office at OU. This does not identify what study you were in or any of your study results, but

simply indicates that you received compensation for study participation.

Contact Information

If you have any questions regarding this study, please contact Dr. Julie Suhr, <u>suhr@ohio.edu</u>, 593-1091, or Dr. Deborah McAvoy, <u>mcavoy@ohio.edu</u>, 593-1468.

 If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

By signing below, you are agreeing that:

- you have read this consent form (or it has been read to you) and have been given the opportunity to ask questions and have them answered
- you have been informed of potential r sks and they have been explained to your satisfaction.
- you understand Ohio University has no funds set aside for any injuries you might receive as a result of partic pating in this study
- you are 18 years of age or older

1

- your participation in this research is completely voluntary
- you may leave the study at any time. f you decide to stop participating in the study, there will be no penalty to you and you will not lose any benefits to which you are otherwise entitled.

Signature	Date
Printed Name	

Version Date: April 13, 2011

Driving newspaper advertisement.

Interested in helping us learn more about cognitive changes in aging that are related to driving skills?

We are looking for community-dwelling adults ages 60 and over who have been active drivers in the past 2 years to participate in a driving study, using a driving simulator. Your participation in the first part of the study will take about 4 hours and you will receive 40 dollars for your participation, as well as feedback about your performance on the cognitive tests. It is important for you to note that the driving simulator is NOT a test of your basic driving skills and does not measure your driving ability, and you will not receive feedback about your driving performance in the simulator.

To participate or to ask questions about the study, contact Dr. Julie Suhr at 593-0910 or suhr@ohio.edu.
Appendix B: Supplemental Statistical Analyses

Table 8

Driving Variable	Percentage of Participants that Indicated Yes
Use of Freeways (often- very often)	55.8%
Use of Highways (often- very often)	88.31%
Restrict Driving in Some Way	54%
Accident in Past Year	7.8%
Near Miss in Past Year	31.2%
Gotten Lost in Past Year	24.7%
Traffic Violations with	6.5%
Loss of Demerit Points in	
Past Year	
Backed into Things	9.1%
Besides Other Cars in Past	
Year	

Descriptive Data on Self-Reported Driving Performance

Table 9

Correlates of Neuropsychological Measures (Raw Scores) Hypothesized to be Predictive of Driving with UFOV Subtests

	UFOV Subtest 1	UFOV Subtest 2	UFOV Subtest 3
RBANS line	03	13	.01
orientation			
RBANS figure copy	02	19*	11
WAIS-IV Block	30**	31**	24**
Design			
RBANS digit span	11	14	14
TMT A	.16*	.29**	.34**
TMT B	.16	.32**	.35**
D-KEFS Interference	.21*	.18*	.25**
D-KEFS Switch	.24*	.18	.27**

Note. D-KEFS = Delis–Kaplan Executive Function System; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; TMT = Trailmaking Test; WAIS-IV = Wechsler Adult Intelligence Scale.

Table 10

	Accident in Past Year	Near Miss in Past Year	Gotten Lost in Past Year	Traffic Violations in Past Year	Backed into Non- Cars in Past Year
UFOV Crash	.055	.152	039	019	016
Statement					
RBANS Line	.096	.157	.091	.026	.067
Orientation					
RBANS	.037	055	026	072	088
Figure Draw					
WAIS-IV	141	185	161	078	111
Block Design					
RBANS	.167	017	.079	.165	097
Digit Span					
TMT A	.168	.076	.260*	.013	.234*
D-KEFS	159	.060	111	055	.254*
Interference					
D-KEFS	106	120	083	.221	.145
Switch					
TMT B	032	.160	.106	083	.076

Correlations of Self-Reported Driving with UFOV and Neuropsychological Measures

Note. D-KEFS = Delis–Kaplan Executive Function System; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; TMT = Trailmaking Test; WAIS-IV = Wechsler Adult Intelligence Scale. Spearman's rho was used, as UFOV Crash Risk Statement is a categorical variable.



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