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Useful Field of View and Other Neurocognitive Indicators of Crash Risk in Older Adults

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*Older adults represent a rapidly growing segment of the driving population. Although most older drivers are safe, research has shown that this group has more crashes per mile driven than most other age groups. The purpose of the present investigation was to examine the utility of a set of commonly used neuropsychological/cognitive tests in comparison to a newer measure of visual attention (Useful Field of View; UFOV®) in predicting state-recorded, at-fault crashes over the previous five years in a group of older adult drivers. Participants (*N *= 239) completed tests of mental status, visual attention, memory, and UFOV®. Results show that among all cognitive tests administered, UFOV® was most strongly related to crash involvement, with high levels of sensitivity (86.3%) and specificity (84.3%) at the standard cutoff score of 40% reduction. Practical implications for the assessment of crash risk are discussed.*

KEY WORDS: driving; older adults; visual attention; neuropsychology.

INTRODUCTION

In 1990, adults 65 years of age and older accounted for 12.6% of the population (U.S. Department of Commerce, 1990) with projections that by the year 2030 approximately 22% of the population will be in this age group

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(Bronfenbrenner, McClelland, Wethington, Moen, & Ceci, 1996). As the number of older adults in the population increases, there is also rapid growth in the number of older drivers (Barr, 1991). Estimates show that the number of older drivers will increase from about 10% of all drivers in 1988 to 28% by the year 2000 and 39% by the year 2050 (Malfetti, 1985; National Safety Council, 1989). Further, the number of miles driven annually by this age group increased during the 1980s (Barr, 1991; Transportation Research Board, 1988).

There is some concern regarding the safety of these older drivers on the road. Research has shown that when the number of miles driven is taken into account, older drivers have more automobile crashes than any other adult age group (Evans, 1988a). Further, it appears that older adults are more vulnerable to injury in the event of a crash (Barr, 1991; Brouwer & Ponds, 1994; Evans, 1988b). Although there is a subset of older drivers involved in vehicle crashes, it is important to note that the majority of this group remain crash-free (Evans, 1991). Thus, any decision about the right to continue to drive that is based upon age is clearly discriminatory and inappropriate. In fact, an international panel of experts recently agreed that decisions about at-risk drivers should be based upon empirically derived criteria (Lundberg *et al.*, 1997).

In our society, driving is a particularly important activity for older adults in terms of maintaining mobility and independence as long as possible. Most older adults rely on the automobile as their primary mode of transportation (Jette & Branch, 1992). However, traffic crashes pose a health risk both in terms of individual suffering and costs to society. Therefore, researchers have attempted to find ways to distinguish those older drivers at risk of crashing from safe older drivers (Ball & Owsley, 1991; Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Odenheimer *et al.*, 1994; Owsley *et al.*, 1997).

In determining the factors associated with crash risk, investigators have examined several different outcome variables including self-report measures of crash involvement, driving simulator performance, road test performance, and state-recorded accident reports. Ball and Owsley (1991) have reported previously on the strengths and weaknesses of the different dependent measures. Self-report measures, while being the most widely used, do not always coincide with state records, and impaired older drivers may underreport crash involvement to protect their driving status. A driving simulator allows for a controlled testing environment, but many simulators do not replicate the complexities of driving in the real world. The road test provides a more ecologically valid measure of driving competence, but the lack of environmental control, as well as safety issues make this measure less than ideal. Odenheimer *et al.* (1994) noted that the road test has limited validity due to unavoidable variability in the weather, traffic, and traffic events. Although a closed course provides for safety and repeatability, it also lacks the validity of the real world (Odenheimer *et al.*, 1994).

There are several advantages to using state-recorded accident reports (Ball & Owsley, 1991; Odenheimer *et al.*, 1994) as the driving outcome measure. In particular, a detailed record of the event is provided. In addition, data from this type of record influence public policy. Because automobile crashes are a rare event, state accident records are a rather insensitive measure of driving ability. That is, a person may exhibit poor driving skills and never be involved in a reported crash. Therefore, if relationships are found with state records, they would likely be stronger in road or simulator testing.

With regard to predictor variables, it should be noted that driving is a very complex task involving cognitive, motor, and sensoriperceptual functioning. Therefore, research has examined a wide range of variables in these domains (Ball *et al.*, 1993; Marottoli, Cooney, Wagner, Doucette, & Tinetti, 1994). In particular, measures of visual functioning have been extensively examined. Despite the fact that driving is a highly visual task, studies to date have failed to find a strong link between driving in the elderly and standard measures of vision such as visual acuity and visual field sensitivity (Ball *et al.*, 1993; Burg, 1967, 1968). This is not to say that impaired vision does not pose a risk, but rather that the majority of people who crash have adequate vision.

Several studies have demonstrated a relationship between cognitive impairment and poorer driving performance in older adults (Johansson *et al.*, 1996; Marottoli *et al.*, 1994). Some studies have focused on specific groups including patients with dementia (Cooper, Tallman, Tuokko, & Beattie, 1993; Fitten *et al.*, 1995), traumatic brain injury (Korteling & Kaptein, 1996), or cerebrovascular accident (Galski, Ehle, & Williams, 1996). Other studies have included healthy elderly participants. For example, Odenheimer *et al.* (1994) tested 30 participants on measures of mental status (Mini-Mental State Exam), visual attention (Trail Making Test), and memory (Wechsler Memory Scale). The participants were selected to reflect a range of cognitive skills and included six participants with a diagnosis of dementia. Correlations ranging from .51 to .72 were found between an in-traffic road test and the scores on the cognitive tests. Another study included both healthy elderly and persons with dementia, and found that cognitive impairment was associated with poorer driving performance (*r*s ranging from .19 to .68) on a road test (Hunt, Morris, Edwards, & Wilson, 1993). The cognitive domains assessed included general cognition, attention, memory, and language. Brouwer and Ponds (1994) also reported that participants who performed poorly on tests of visual search and attention (e.g., Trail Making A Test) also tended to perform poorly on a road test.

One cognitive skill that appears to be particularly important for driving is attention (Parasuraman & Nestor, 1993). Recently, Ball and colleagues have demonstrated that a novel measure of visual attention, the Useful Field of View (UFOV®) is an excellent predictor of increased crash involvement based on state-recorded accident reports of older drivers (Ball *et al.*, 1993; Owsley *et al.*, 1997). The UFOV® is a measure of the size of the visual area within which targets can capture attention during a brief inspection period. The UFOV® test consists of three tasks which assess (a) speed of visual processing, (b) the ability to divide attention, and (c) selective attention abilities. The composite score is expressed as a percentage reduction of the Useful Field of View, ranging from 0% reduction (normal) to 90% reduction. This test is described in more detail in the Method section. A 3-year prospective study on 294 older drivers has shown that high risk drivers (UFOV® reduction of 40% or more) were 2.3 times more likely to be involved in at-fault vehicle crashes during this time period than low-risk drivers (Owsley *et al.*, 1997). Findings such as this should lead to practical methods for identifying high-risk older drivers.

Those in a medical setting are often called upon to advise both older adults and their family members regarding concerns about the older adult's ability to drive safely (Carr, 1993). Outside of formal on-the-road testing, simple protocols for use in the offices of health care professionals have only recently been considered (Marottoli *et al.*, 1994; Martinez, 1995; Owsley, 1997). The purpose of the current investigation was to examine the utility of a set of commonly used neurocognitive tests, as well as UFOV®, in predicting state-recorded, at-fault crash involvement. Measures of mental status, visual attention, and visual memory were used. It was hypothesized that the cognitive measures would be significantly associated with crash status. However, it was thought that addition of the UFOV® score would significantly enhance classification of safe and unsafe older drivers above the rate achieved using the more traditional neuropsychological measures.

METHOD

Participants

The participants in the present study were a subset of those recruited for a larger study on driving in older adults (Ball *et al.*, 1993). The recruitment population for the larger study included all licensed drivers 55 years and older living in Jefferson County, AL (N = 118,553). The crash data were obtained from the Alabama Department of Public Safety. A sampling strategy was utilized in order to produce a stratified sample balanced with respect to age and crash frequency over the previous 5 years. In particular, it was important to oversample drivers with a crash in the prior 5-year period to obtain a range of crash involvement. Therefore, the total population was sorted into cells by age group (55–59, 60–64, 65–69, 70–74, 75–79, 80–84, 85+) and crash frequency (0, 1–3, 4 or more). Next, 75 drivers were randomly selected from each of the 21 cells, and contact letters were sent to all those listed in the local phone directory (1,342 persons). Recruiting continued until approximately 300 older adults were enrolled in the study. From the final sample who participated in the entire protocol (n = 294), a total of 251 participants received all the cognitive tests. Twelve participants were excluded from the present analyses due to poor visual acuity. Previous research has shown that those with visual acuity worse than 20/50 uniformly failed the first subtest of the UFOV® measure (Owsley, Ball, & Keeton, 1995). Thus, the current analyses were based on a sample of 239 participants (112 female, 127 male) with relatively good visual function. The sample included Caucasian (82%) and African American (18%) participants with a mean age of 70.36 years (SD = 8.95). Participants reported an average of 12.34 years of education (SD = 3.43).

Measures and Procedures

Written informed consent was obtained from each individual prior to participation in the study. Approval of the study was granted by the Institutional Review Board of the University of Alabama at Birmingham. As mentioned previously, this study was part of a larger study examining driving in older adults in which five general domains were assessed: visual sensory function, neurocognitive functioning, UFOV®, driving habits, and eye health (Ball *et al.*, 1993). For the current analyses, the following measures were used.

Mattis Organic Mental Syndrome Screening Examination. The MOMSSE (Mattis, 1976) is a brief (15–20 minute) neuropsychological screening instrument consisting of items of several WAIS subtests, a Benton geometric figure, and items from the Eisenson Test of Aphasia. Domains of functioning assessed by this instrument include premorbid intellectual ability, verbal abstract ability, attention, verbal and nonverbal short-term memory, language, and constructional abilities. A total performance score was derived (higher scores represent more impairment) and used for analysis in the present study.

Trail Making Test. The Trail Making Test, Parts A and B (Spreen & Strauss, 1991), is a neuropsychological instrument used to assess speed of visual search, attention, mental flexibility, and motor functioning. This instrument has demonstrated acceptable reliability (coefficient of concordance = .78 and .67 for Parts A and B, respectively; Lezak, 1983). Additionally, this task provides an opportunity to observe one's ability to deal with multiple stimuli, a skill that is important in driving. Scores were recorded as the time required for completion. Trail Making Parts A and B were discontinued at 120 and 240 seconds, respectively.

Wechsler Memory Scale–Visual Reproduction Subtest. The WMS-VR (Wechsler, 1945) subtest was used to assess visual memory. It requires memorization of a visual stimulus and construction of this stimulus from memory. The total raw score was used in the analyses.

Rey-Osterrieth Complex Figure Test. The Rey-O (Lezak, 1983; Spreen & Strauss, 1991) was developed to assess perceptual organization and planning, as well as visual memory. The task involves first copying a complex figure and then attempting to draw the figure from memory. For the present investigation, accuracy scores for the copy trial and the immediate recall trial were used. Research on normal populations has indicated that there is minimal decrement in copy scores with age and little decline in recall scores until the eighth decade (Spreen & Strauss, 1991).

Useful Field of View (UFOV®). UFOV® was assessed using the UFOV® Visual Attention Analyzer, Model 2000 (Visual Resources, Inc., Chicago, IL). This microprocessor-based instrument uses three subtests that provide a reliable measure of UFOV® size, expressed in terms of the percentage of reduction (0 to 90%) of a maximum 35° radius field (Ball, Roenker, & Bruni, 1990). Subtests were presented on a 20-inch (diagonal) video monitor at a viewing distance of 23.5 cm. Targets were presented at high contrast (99%), and subtended 5.1 horizontal × 3.2 vertical degrees of visual angle. In the first subtest, designed to assess speed of visual processing, the participant was required to identify a target of varying duration presented in the fixation box. The target was the silhouette of a car or a truck. The second subtest, designed to assess the ability to divide attention, required the localization of a simultaneously presented peripheral target (a silhouette of a car) in addition to the identification of the central target. The peripheral target appeared unpredictably at any one of 24 different peripheral locations along 8 radial spokes (4 cardinal and 4 oblique) at 3 eccentricities (10°, 20°, and 30°). The duration of the display was varied to measure speed of processing for this divided attention task. The third subtest, designed to assess selective attention abilities, was the same as the second task with the exception that the peripheral target was embedded in distractors (triangles). Performance on the UFOV® test is then expressed as a function of three variables: the minimum target duration required to perform the central discrimination task (Subtest 1), the ability to divide attention between central and peripheral tasks successfully (Subtest 2), and the ability to filter out distracting stimuli (Subtest 3). For Subtest 1, the minimum duration that subjects can perform the task with 75% correct is noted. For Subtests 2 and 3, the best fitting line reflecting the relationship between eccentricity and localization errors is computed for each test duration, and UFOV® size is defined as the eccentricity at which a subject can localize the peripheral target 50% of the time. Performance on the subtests is combined to arrive at three scores representing the extent of difficulty with regard to speed of processing, divided attention, and selective attention. These scores range from 0 (*no problem*) to 30 (*great difficulty*). Deficits in each of these abilities have been shown to be additive in their effect on UFOV® size (Ball *et al.*, 1990). Therefore, to summarize UFOV® performance, the three scores are combined to yield a score between 0 and 90, that represents the percentage reduction of a maximum 35° radius field.

Crash Status. State driving records for each participant were obtained for the 5-year period immediately preceding this study. Three raters, blind with respect to other data in the study as well as the identity of the research participant, independently reviewed each accident report to determine whether the research participant was at fault. There was 100% agreement in determining those collisions where the participant was clearly not at fault. Although concordance was not perfect for at-fault crashes (83%), all raters agreed that the study participant was at least partially at-fault in the crash. Participants were then classified as safe drivers (0 at-fault crashes) and crashers (one or more at-fault crashes). The sample included 115 drivers without an at-fault crash and 124 persons who were involved in one or more at-fault crashes (M = 2.28, SD = 1.03, range = 1–5).

RESULTS

Table I contains the mean scores for crashers and noncrashers on all of the administered tests, as well as standard deviations and t-test values. The two groups differed significantly on every measure. The range of scores for all participants is also included in Table I. There was considerable variability on test performance for all measures indicating a range in cognitive status of the participants.

Table I. Descriptive Statistics for All the Cognitive Measures

Measure	Crashers *M* (*SD*)	Noncrashers *M* (*SD*)	*t* test[a] (*df* = 237)	All participants Min.	All participants Max.
MOMSSE	6.58 (3.59)	5.00 (2.90)	-3.73	0.00	19.50
Trails A time (sec)	60.47 (27.58)	48.78 (18.79)	-3.80	18.00	120.00[b]
Trails B time (sec)	147.35 (65.99)	124.81 (52.74)	-2.90	49.00	240.00[b]
WMS-VR	6.43 (3.81)	7.70 (3.10)	2.81	0.00	14.00
Rey-O Copy	28.07 (7.70)	30.57 (6.27)	2.74	2.00	36.00
Rey-O Immediate	8.25 (7.22)	10.79 (7.94)	2.59	0.00	32.00
UFOV®	52.56 (20.55)	29.90 (16.49)	-9.36	7.50	90.00

[a] All *ps* $< .01$.

[b] Trail Making Parts A and B were discontinued at 120 and 240 seconds, respectively.

To identify the best set of predictor variables, a series of logistic regression models were analyzed using SAS PROC LOGISTIC. For each of the models, the outcome variable was at-fault crash status (i.e., no prior crashes, one or more prior crashes). The first model was designed to evaluate the predictive ability of the more traditional cognitive or neuropsychological tests. The second model included all the variables entered in the first model with the addition of the UFOV® reduction score. The third model evaluated the UFOV® score alone. Residual and diagnostic statistics (e.g., Pearson residual, deviance residual, dfbeta, leverage) were examined for each model to insure that individual cases did not exert undue influence on the results. Summary statistics for all three models are shown in Table II.

The first model, which included the more traditional cognitive tests (MOMSSE, Trails A time, Trails B time, WMS-VR score, Rey-O copy score, and immediate recall scores), was statistically significant, $\chi^2(6, N = 239) = 20.02, p < .01$, indicating that these variables, as a set, reliably distinguished between crashers and noncrashers. In this model, MOMSSE score, Wald $\chi^2(1, N = 239) = 4.33, p < .05$, and Trails A time, Wald $\chi^2(1, N = 239) = 4.92, p < .05$, uniquely accounted for differences in the outcome of crash status. Classification success was modest with an overall rate of 58.6%. The model correctly identified 57.3% of the crashers (sensitivity) and 60.0% of the noncrashers (specificity).

The second model, which added the participants' UFOV® reduction score to the neuropsychological variables, was analyzed and found to be statistically significant, $\chi^2(7, N = 239) = 84.24, p < .001$. The second model (including the UFOV® score) can be compared to the first model containing only the neuropsychological variables by calculating the difference in the chi-square statistic. This likelihood ratio test showed that the UFOV® score added unique information in terms of accounting for crash status,

Table II. Results of Logistic Regression Models

Measure	Wald χ^2	Likelihood ratio	Unstandardized coefficient	*SE*	Odds ratio	90% CI	*p*
Model 1: Overall log-likelihood = 20.02; R^2 = .06							
MOMSSE	4.33	4.45	0.127	0.060	1.14	1.03–1.26	.04
Trails A time	4.92	5.12	0.020	0.009	1.02	1.01–1.04	.03
Trails B time	1.37	1.38	−0.005	0.004	1.00	0.99–1.00	.24
WMS-VR	0.02	0.01	0.007	0.059	1.01	0.91–1.11	.90
Rey-O Copy	0.01	0.01	−0.002	0.026	1.00	0.95–1.04	.93
Rey-O Immediate	0.16	0.16	−0.010	0.024	0.99	0.95–1.03	.69
Model 2: Overall log-likelihood = 84.24; R^2 = .25							
MOMSSE	2.11	2.13	0.104	0.072	1.11	0.99–1.25	.15
Trails A time	0.86	0.88	0.009	0.011	1.01	0.99–1.03	.35
Trails B time	5.02	5.22	−0.011	0.005	0.99	0.98–1.00	.03
WMS-VR	0.48	0.49	0.047	0.068	1.05	0.94–1.17	.49
Rey-O Copy	0.16	0.16	−0.122	0.031	0.99	0.94–1.04	.69
Rey-O Immediate	0.24	0.25	0.013	0.027	1.01	0.97–1.06	.62
UFOV®	41.44	64.22	0.079	0.012	1.08	1.06–1.10	.00
Model 3: Overall log-likelihood = 76.04; R^2 = .23							
UFOV®	47.90	76.04	0.068	0.010	1.07	1.05–1.09	.00

$\chi^2(1) = 64.2, p < .001$. Also, classification was improved at an overall rate of 77.4%, with a sensitivity of 76.6% and specificity of 78.3%.

A third model, with only the UFOV® score, was tested and also found to be statistically significant, $\chi^2(1, N = 239) = 76.04, p < .001$, Odds Ratio (OR) = 1.07, 90% CI OR = (1.05–1.09). This indicates that the UFOV® measure alone reliably distinguished between crashers and noncrashers. The overall classification rate was 85.4%, with a sensitivity of 86.3% and specificity of 84.3%. A likelihood ratio test revealed no significant difference between the third model with only UFOV® and the second model with UFOV® and the additional neuropsychological predictors, $\chi^2(6) = 8.20, p > .25$.

The other cognitive variables were each analyzed individually to determine if another measure might reliably predict crashing on its own. The results of those analyses are presented in Table III. Each measure was significantly associated with crash status. However, the level of sensitivity and specificity was much less than what was achieved using only the UFOV® reduction score. Table III also displays the correlations between the well-known measures of mental status, visual attention, and memory with the UFOV® score. As might be expected, all measures are significantly correlated with UFOV® score (*p*s < .001).

Table III. Results of Logistic Regression for Each Cognitive Measure and Correlation with UFOV® Score

Measure	Wald χ^2	Likelihood ratio	p	Odds ratio	Sensitivity	Specificity	Correlation with UFOV®
MOMSSE	12.52	13.69	.0002	1.16	61.3	58.3	.45
Trails A time	12.8	14.30	.0002	1.02	57.3	62.6	.51
Trails B time	8.0	8.32	.0039	1.00	50.8	60.0	.52
WMS-VR	7.5	7.81	.0052	0.90	66.1	52.2	-.46
Rey-O Copy	7.0	7.62	.0058	0.95	50.0	61.7	-.35
Rey-O Immediate	6.4	6.63	.0100	0.95	64.5	47.0	-.42
UFOV®	47.9	76.04	.0001	1.07	86.3	84.3	1.00

To facilitate the use of the UFOV® measure in a clinical setting, it was determined that a dichotomous pass–fail measure should be examined. Previous work on the predictive ability of UFOV® for crashing has found that a cut point of 40% reduction results in optimal classification rates (Ball *et al.*, 1993). With the current sample, an additional model was analyzed relating crash status to this dichotomous UFOV® pass–fail distinction. The model was statistically significant, $\chi^2(1, N = 239) = 131.92, p < .0001$, OR = 33.92, 90% CI OR = (18.54–62.05). In this analysis, the classification rates were identical to the model using the continuous UFOV® variable (85.4% overall, 86.3% sensitivity, 84.3% specificity).

Additional correlational analyses were conducted to examine the relationships of demographic variables (age, gender, and education) to crash status and UFOV® performance. Because the sample was stratified based on age and crash status, this association was excluded. The analyses revealed that crash status was not related to gender or education (ps > .25). UFOV® score was associated with age ($r = .56, p < .01$) and education ($r = -.20, p < .01$), but not with gender ($p > .50$).

DISCUSSION

In terms of cognitive assessment of driving risk, the results of the current investigation support the use of a stand-alone measure of visual attention (UFOV®) for assessing older adults' risk for automobile crashing. The Useful Field of View was compared to a set of well-known, commonly used neurocognitive tests and was found to provide excellent predictive validity. The traditional measures of mental status (MOMSSE), attention (Trail Making), and visual memory (WMS-VR, Rey-Osterrieth) did reliably distinguish crashers from noncrashers. However, the addition of UFOV® to the other cognitive tests significantly improved classification rates.

The model including only the UFOV® reduction score was the most parsimonious and also provided the best group separation in terms of crash status. The UFOV® measure yielded a sensitivity of 86.4% and a specificity of 84.3%. None of the other individual cognitive measures approached this level of classification. To facilitate the applied use of the UFOV® measure, a model was analyzed based on a pass–fail UFOV® grouping using a cutoff score of 40% reduction or greater for failure. In the current analyses, the pass–fail distinction provided rates identical to those obtained using the continuous UFOV® variable.

The sampling strategy utilized in this study was the case-control methodology, with roughly equal numbers of subjects involved or not involved in automobile accidents over the previous 5 years. Although the odds ratios and sensitivity calculations do not change when the prevalence rate in the sample differs substantially from the prevalence rate in the entire population, the predicted probability of being involved in an accident as a function of one's score on a predictor variable, which also reflects the diagnostic utility of that predictor, does change substantially when there is a marked difference between the sample and population base rates. Records from the Alabama Department of Public Safety indicate that over the 5-year period, 21% of all licensed drivers within this age range were involved in at least one automobile accident. Using the results from the present study in conjunction with an assumed population base rate of .21, Bayes' theorem indicates that the predicted probability of having at least one accident over a 5-year period is .59 for any individual with a UFOV® score of 40 or more. By contrast, the predicted probability of at least one accident over 5 years is only .04 for those with UFOV® scores less than 40 on the basis of the present results and an assumed overall population prevalence rate of .21.

The identification of a clinical measure that is able to reliably distinguish safe from unsafe older drivers has tremendous implications for health care professionals in terms of making driving recommendations for older adults. Of particular importance to these professionals, the UFOV® test is easily administered in an office setting with the use of a personal computer. The scoring of the test is also automated, thus reducing opportunities for scoring errors to occur. The software provides an overall score indicating the percentage reduction in Useful Field of View. In addition, the pass–fail criterion (40% reduction) can be used to assist in making decisions regarding an older person's driving status.

It is important to note that the focus of this paper was on assessment of cognitive variables related to driving performance. Many other factors play a role in crash risk including impairments in vision (Hofstetter, 1976; Johnson & Keltner, 1986), certain diseases (Morgan & King, 1995; Reuben, 1993), and medication usage (Koepsell *et al.*, 1994; Ray, Fought, & Decker, 1992). A complete assessment of driving fitness would include measures of all relevant areas (Carr, 1993; Owsley, 1997).

This study has several limitations. The crash data were obtained over a 5-year period prior to the assessment of the cognitive domains. It is possible that, for the crash-involved participants, cognitive changes may have occurred after a collision took place. To examine the possibility that a crash may have actually caused trauma leading to cognitive changes, a post hoc analysis of injuries was conducted. Of the 124 participants involved in at-fault crashes, only 25 (20%) suffered an injury as a result of the automobile crash. A *t* test comparing the injured drivers with the uninjured, yet crash-involved drivers, indicated no significant differences in UFOV® performance. Therefore, it seems unlikely that the cognitive differences observed in this study were primarily a result of brain injury associated with head trauma.

While there are limitations to using a retrospective design, the primary rationale for using the 5-year retrospective period in the current study was to oversample drivers who had experienced a crash in order to examine variables potentially related to crashing. A prospective study would require that an extremely large cohort be followed for many years in order to obtain enough crashes to have sufficient power to detect relationships.

Therefore, it is also important to note that the current sample is not representative of the older adult driving population. This study used a case-control design in which crash-involved older drivers were compared to crash-free drivers. Thus, the current sample includes a greater number of poor drivers than would be found in a random sample. Using a random sample, one might not find as strong a relationship between crashing and the cognitive measures evaluated due to the predominance of good drivers (see Ball *et al.*, 1993, for a discussion).

In the current study, the specific cognitive tests were chosen based on previous research identifying cognitive domains related to driving performance (Brouwer & Ponds, 1994; Hunt *et al.*, 1993; Odenheimer *et al.*, 1994). Thus, measures assessing mental status, visual attention, and visual construction and memory were included. Another consideration was to select well-known measures with a history of psychometric reliability and validity (Lezak, 1983; Spreen & Strauss, 1991). Ease of administration also played a role in test selection. There may be other existing cognitive measures that can provide better prediction in crashing than those examined here.

Another domain to consider with regard to older driver safety is driving habits or driving exposure. Studies have shown that older adults tend to self-regulate or avoid certain driving situations. In particular, it appears that many older drivers limit their exposure to driving situations that are generally believed to be more difficult, such as driving in heavy traffic or in the rain (Hennessy, 1995; Planek, Condon, & Fowler, 1968). In one study, older adults with visual and/or attentional impairment reported more avoidance of challenging driving situations (e.g., night driving) than those free of impairment (Ball *et al.*, 1997). However, Owsley, Ball, Sloane, Roenker, and Bruni (1991) and Ball *et al.* (1993) found that older drivers with visual and cognitive processing impairments were at a greater risk for crash involvement than those without these problems, despite self-reports that many of these functionally impaired drivers avoided difficult driving situations.

This investigation also has several strengths. In particular, there was variability in cognitive test scores indicating that the sample included a range of cognitive skills. Also, by oversampling persons involved in crashes, there were sufficient numbers of both crashers and noncrashers to compare various cognitive measures. In general, the sample was larger than has been previously examined with respect to cognitive measures and driving ability (Hunt *et al.*, 1993; Odenheimer *et al.*, 1994). Another strength of the study was the use of state-recorded accident reports. The advantages of this outcome measure have been noted previously. In addition, crash status is most often used in studies focusing on driver safety.

It is important to reiterate the significance of driving for mobility and maintaining independence in older adults. Decreased mobility in the elderly has been linked to a variety of adverse health outcomes including increased mortality (Donaldson, Clayton, & Clarke, 1980), an increased number of acute conditions (Branch & Meyers, 1987), increased depressive symptoms (Marottoli *et al.*, 1997), and a decline in overall functioning (Branch, Katz, Kniepmann, & Papsidero, 1984; Manton, 1988). Therefore, research and clinical efforts should focus not only on identification of high-risk drivers but also on interventions to reduce the risk of crashes in those drivers and thereby prolong their ability to drive as long as possible. Toward this end, other research on the Useful Field of View provides very promising results by showing that the UFOV® may be expanded with practice (Ball, Beard, Roenker, Miller, & Griggs, 1988; Roenker, Cissell, & Ball, 1997). Also, in a recent training study, older drivers were able to expand the size of their attentional field and this skill transferred to road test performance, resulting in fewer dangerous maneuvers during an open-road driving evaluation (Roenker *et al.*, 1997). These results suggest that the UFOV® measure may be useful in both identification of unsafe older drivers and as a training tool with the potential to improve driving skills in this population.

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