1040-5488/05/8208-0724/0 VOL. 82, NO. 8, PP. 724–731
OPTOMETRY AND VISION SCIENCE

ORIGINAL ARTICLE

Cumulative Meta-analysis of the Relationship Between Useful Field of View and Driving Performance in Older Adults: Current and Future Implications

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ABSTRACT: *Purpose.* Driving is a complex behavior that requires the utilization of a wide range of individual abilities. Identifying assessments that not only capture individual differences, but also are related to older adults' driving performance would be beneficial. This investigation examines the relationship between the Useful Field of View (UFOV) assessment and objective measures of retrospective or concurrent driving performance, including state-recorded accidents, on-road driving, and driving simulator performance. *Method.* The PubMed and PsycINFO databases were searched to retrieve eight studies that reported bivariate relationships between UFOV and these objective driving measures. Cumulative meta-analysis techniques were used to combine the effect sizes in an attempt to determine whether the strength of the relationship was stable across studies and to assess whether a sufficient number of studies have been conducted to validate the relationship between UFOV and driving performance. *Results.* A within-group homogeneity of effect sizes test revealed that the samples could be thought of as being drawn from the same population, Q [7] = 11.29, p (one-tailed) = 0.13. Therefore, the effect sizes of eight studies were combined for the present cumulative meta-analysis. The weighted mean effect size across the studies revealed a large effect (Cohen's d = 0.945), with poorer UFOV performance associated with negative driving outcomes. This relationship was robust across multiple indices of driving performance and several research laboratories. *Conclusions.* This convergence of evidence across numerous studies using different methodologies confirms the importance of the UFOV assessment as a valid and reliable index of driving performance and safety. Recent prospective studies have confirmed a relationship between UFOV performance and future crashes, further supporting the use of this instrument as a potential screening measure for at-risk older drivers. (Optom Vis Sci 2005;82:724–731)

Key Words: Useful Field of View, cumulative meta-analysis, driving, elderly, mobility

During a routine drive on any highway, individuals clearly demonstrate a wide range of driving ability. Individual differences in driving ability are reflected in crash statistics and as a result, highway safety researchers have sought to determine the characteristics that make some drivers safer than others. Until recently, this research has met with limited success for two primary reasons. First, few measures have adequately captured individual characteristics, or predictor variables, related to differences in driving performance. Second, constructing realistic measures of driving performance, or outcome variables, has been difficult. The purpose of this article is to examine the significance of one promising indicator, performance on the Useful Field of View (UFOV) assessment, and its association with objective indices of retrospective or concurrent driving performance.

Because driving is a complex task, it is unlikely that an assessment that measures visual or sensory function alone, such as those most commonly used in department of motor vehicles settings,

Drs. Ball and Roenker own stock in Visual Awareness Inc., which owns the patent for Useful Field of View testing and training software.

would be sufficient to identify those at elevated risk for crash involvement. (A thorough discussion of the relationship of visual sensory indices to driving performance has previously been published by Owsley & McGwin.[1]) Visual information processing skills have a great deal of face validity in that they require adequate visual sensory function as well as the ability to respond adequately to more complex information for predicting the execution of safe driving practices. One such skill is visual attention, and several studies from the early 1970s suggested that impaired visual attention was linked to crash involvement.[2–4] However, these findings were not further explored until the relatively recent body of work[5,6] that examined a higher-order visual/cognitive process that has been coined the useful field of view.[7]

What is Useful Field of View?

The concept of the useful field of view was originally described by Sanders[8] who used the term "functional visual field" to define the visual field area over which information can be acquired in a brief glance without eye or head movements. Subsequently, Verriest and colleagues at the 6th International Visual Field Symposia described the useful field of view as an "occupational visual field" and distinguished it from the clinical visual sensory field typically evaluated by perimetry in ophthalmologic settings.[9] Unlike clinical visual fields, which require detection of threshold targets, the UFOV test requires both identification and localization of suprathreshold targets through subtests that primarily tap speed of information processing, ability to divide attention, and susceptibility to distraction.[10] Although UFOV test performance relies in part on visual sensory input, individuals with intact visual sensory fields can also exhibit poor performance.[11] Owsley and colleagues demonstrated that UFOV test performance relies on higher-order cognitive abilities as well as visual sensory function.[11] Today, the useful field of view is most often assessed with a specific computer-based measure, the UFOV assessment.[7]

The UFOV test is performed binocularly and measures one's ability to process rapidly presented, increasingly complex information within a single glance through three increasingly difficult visual subtests incorporating stimulus identification, divided attention, and selective attention. The first subtest requires the identification of a target (silhouette of a car or truck) presented in a central fixation box. The second subtest measures divided attention and involves identification of the central target along with localization of a simultaneous peripheral target (silhouette of a car). The third subtest consists of these same two tasks, but also includes visual distractors (triangles of the same size and luminance as the targets) that fill the rest of the visual display. Peripheral targets are randomly presented in 24 different locations at 10°, 20°, or 30° eccentricity along eight radial spokes. When viewed at a distance of 23.5 cm with a 20-inch monitor, targets subtend 5.1 horizontal times 3.2 vertical degrees of visual angle. Through years of research, administration of the UFOV test has been modified from the earliest versions administered by the Visual Attention Analyzer.[12] Beginning in 1998, the test is administered by personal computer with comparable validity and reliability.[12] Test–retest reliabilities of the scores from the UFOV PC versions are high, and performance correlates well with performance on the original version, which was used in the studies included in the present article.[12]

Measures of Driving Performance

Multiple studies have been conducted examining the relationship between UFOV test performance and driving. These studies have used a variety of outcome measures, including on-road driving performance, crashes, simulated driving performance, and self-reported driving performance that assess components of driving ability that are not exhaustive or necessarily unique. Each of these measures has inherent limitations ranging from statistical infrequency (crashes) to potential reporting biases (self-report). The strengths and weaknesses of these different dependent measures have been previously discussed at some length[13,14]; thus, only the highlights of the relevant issues are reported here.

State crash reports provide a rich source of information to assist in identifying risk factors for poor driving in older adults.[15] In particular, detailed crash event records provide such information as the number of cars involved, demographic information on each driver, time of day, weather and road conditions, location, and other specific circumstances of the vehicle crash. State crash records are used by government agencies to formulate public policy and by insurance companies to set rates.

Self-reported crashes provide an alternative for investigators who do not want to obtain state accident reports.[16] An advantage of self-report is that this methodology has yielded more crashes than state records.[16–19] Sometimes vehicle crashes are not reported by either driver and thus are not included in state reports. Because crashes are infrequent events relative to the many miles driven each year, researchers have the burden of trying to predict an improbable event; a statistical advantage is gained with the opportunity to examine the larger number of crash events yielded by self-report.[20]

Nevertheless, there are a number of disadvantages to self-report that serve to highlight the advantages of state records.[5,21] Self-reports are affected by research participants' biases and memory failures.[15] Several investigators have found that older drivers with the highest number of state-recorded crashes are largely males who tend to underreport crash involvement on self-report questionnaires.[15,22] Owsley and colleagues found a low correlation ($r = 0.11$) between the number of self-reported and state-recorded crashes of older drivers over a 5-year period.[14] Other studies have found higher, but nevertheless only moderate, agreement between self-report and state records using a 5-year period of recall ($\kappa = 0.45$)[15] and a 1-year period of recall ($\kappa = 0.45$).[16]

Although several studies have reported a higher number of crashes using self-report rather than state records, McGwin and his colleagues found that this was not always the case.[15] A significantly larger proportion of their sample had at least one or more state-recorded crashes when accident reports were compared with self-report. They divided their sample into three groups: individuals with crashes reported by state records who did not self-report any crashes, individuals with self-reported crashes that did not appear in their state records, and individuals who self-reported at least one crash and also had at least one crash in their state record. Drivers with state-recorded crashes who did not self-report them tended to be older than drivers whose self-reported crashes did not appear in state records. Furthermore, compared with older drivers whose self-reports matched state records, drivers who failed to report their state-recorded crashes were significantly more likely to have contrast sensitivity and peripheral visual field impairment. The researchers warned that any differences in the associations between risk factors and driving performance for individuals with self- versus state-reported crashes could serve to bias estimates of crash risk. For example, glaucoma was identified as a risk factor for state-reported crashes but not for self-reported crashes. The failure to identify an important risk factor by using self-report methodology led these investigators to recommend caution in using self-report and in interpreting the results of studies that rely on self-report methodology alone.

Another method of assessing driving performance is through the use of driving simulators. Driving simulators are designed to mimic actual driving tasks while providing the opportunity to obtain precise, computer-extracted measurements of behavior. A major advantage of using a simulator is that it provides a controlled environment in which to measure driving behavior without the risk or liability of actual on-road testing. A major criticism of driving simulators is that they do not accurately reproduce real-world driving tasks in a manner that is truly interactive. In addition, a number of individuals experience motion sickness during driving simulation.

Relative to simulated driving tasks, road tests are a more direct measure of driving performance. Road tests provide an opportunity to observe and rate driving behavior in actual driving situations and can be given in the driver's own vehicle as well as in a familiar environment. A disadvantage of road tests is that a course must be charted and standardized with specific performance criteria. Although some challenging situations (e.g., heavy traffic, intersections, left-hand turns) may be included in the test, for liability and safety reasons, it may not be feasible or prudent to expose a high-risk driver to such difficult settings.

The purpose of this investigation is to examine the ability of the UFOV assessment to identify older adults at risk for adverse driving outcomes. Studies that used state-reported crashes, simulated driving performance, or on-road driving performance as outcome measures were included, whereas those that involved self-reported automobile crashes as the only measure of driving performance were omitted as a result of possible reporting biases for older adults. Cumulative meta-analysis was used to combine the results of previous studies. It was hypothesized that 1) poorer UFOV performance would be associated with poorer driving performance among older adults, 2) the magnitude of this relationship would remain relatively stable across time, and 3 existing studies would provide sufficient evidence for the strength and durability of this relationship.

METHODS
Identification of Relevant Studies

Relevant studies were identified by searching the PsycINFO and PubMed databases for articles published from January 1, 1985, through October 15, 2003. The keywords used to search the PsycINFO databases included "UFOV," which retrieved 12 articles, and "Useful Field of View," which retrieved 30 articles. A search of the PubMed database using the keyword "UFOV" resulted in 15 citations. Using the terms "useful field of view" as the search criterion resulted in 372 citations. The retrieval of this large number of citations led researchers to subdivide the PubMed search into two more specific inquiries. "Useful field of view" was combined with "driving" and "crashes" resulting in 25 and 10 citations, respectively. Criteria for studies to be included in the meta-analysis were: 1) a sample of adults age 55 and older, 2) no two studies could be based on the same sample, 3) the bivariate association between the UFOV test and driving performance without covarying for the effects of any other measures must be available, 4) the measure of driving performance must be retrospective or concurrent with the UFOV assessment, and 5) the measure of driving performance must be objective rather than self-report. If more than one manuscript was found that included data based on the same protocol, only a single manuscript that reported the direct, unadjusted relationship between UFOV test performance and driving performance using the entire sample was selected.

ANALYSES
Cumulative Meta-analysis

A cumulative meta-analysis was performed to examine the strength of the relationship between UFOV performance and driving ability in older adults using the BASIC meta-analysis software.[23] This software was chosen because of its ability to test for the homogeneity of the studies included, to combine the effect sizes from studies using different statistical indices, and to preferentially weight studies according to sample size. Each study was added to the analysis individually and a new meta-analysis procedure was performed at each wave beginning with the oldest and concluding with the most recent publication. Next, the effect size at each step of the combination of studies was quantified in terms of a simple correlation (r), and Fisher's r to z' transformation was applied to this correlation ($z' = 0.5[\ln(1 + r) - \ln(1 - r)]$). Finally, 95% confidence intervals (CIs) (95% CI $= z' \pm 1.96[1/\mathrm{sqr}(n-3)]$), were calculated for each z' effect size and added to the cumulative effect size plot (Fig. 1).

RESULTS

Eight unique studies met criteria for inclusion in the cumulative meta-analysis. These studies are described with respect to the population from which the sample was drawn, the test statistic reported, sample size, whether the findings were consistent with the hypotheses, and the sample effect size (Table 1).

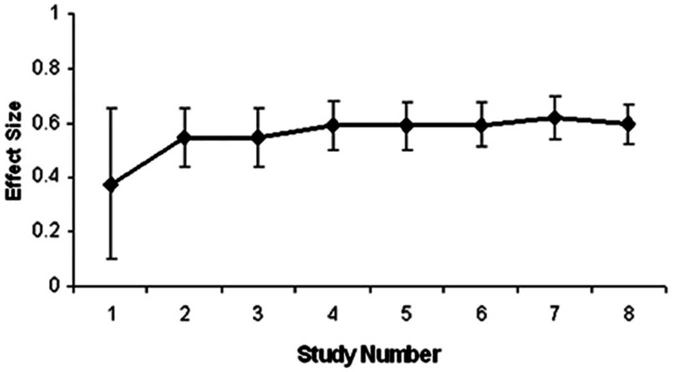

FIGURE 1.
Cumulative meta-analysis of relationship between Useful Field of View and objective driving performance.

TABLE 1.
Studies reporting the direct relationship between Useful Field of View and objective driving performance

Study	Driving outcome	Population	Statistic	df	No.	Weight	Consistent	Sample effect size (z′)
[a]Owsley, 1991[14]	Crashes in last 5 years (state records)	Active licensed drivers 57–83	r = 0.36	51	53	53	+	.3769
[a]Ball, 1993[13]	At-fault crashes (state records)	Active licensed drivers 56–90	r = 0.52	292	294	294	+	.5763
[c]Wood, 1995[24]	Driving performance on a closed-road circuit	Current licensed drivers 60–74 in good ocular health	r = 0.55	8	10	10	+	.6181
[c]Cushman, 1996[25]	On-road driving performance	Current licensed drivers 55+, 91 volunteers, 32 with early AD	χ^2 = 46.0	1	123	123	+	.7114
[b]Rizzo, 1997[29]	Crashes in driving simulator	Current licensed drivers, 21 with AD and 18 controls	χ^2 = 10.925	1	39	39	+	.5891
[b]Duchek, 1998[26]	Driving performance (on-road test)	Current licensed drivers (healthy controls, very mild AD, mild AD)	r = -0.56	53	55	55	+	.6328
[b]Myers, 2000[28]	Driving performance (on-road test)	Patients referred to Bryn Mawr Rehab Adapted Driving Program (61–91)	χ^2 = 23.67	1	43	43	+	.9548
[a]Roenker, 2003[30]	Driving performance (simulator)	Older drivers 55+ with a UFOV reduction of at least 30%	r = 0.422	93	95	95	+	.4477

"Consistent" refers to research findings corresponding to a priori hypotheses (+ for yes, − for no).
[a]Data collected in laboratories operated by one or more authors of current manuscript.
[b]Data collected and analyzed in independent laboratories; manuscript subsequently prepared in conjunction with one or more authors of this article.
[c]Data collected, analyzed, and reported independently. AD, Alzheimer disease; UFOV, Useful Field of View.

Useful Field of View and State-Recorded Vehicle Crashes

The initial study that examined the relationship of UFOV performance to state-recorded vehicle crashes involved a small sample of 53 older adults with a mean age of 70 years who were recruited from the Primary Care Clinic of the School of Optometry at the University of Alabama at Birmingham. These 26 men and 27 women were all licensed drivers who drove at least 1000 miles per year and were living independently in the community.[13] Correlations between participants' state-recorded crashes during the previous 5-year period and potential risk factors such as the health status of the visual system, visual sensory function, visual attention skills (UFOV), and mental status were examined. Only mental status assessed with Mattis Organic Mental Syndrome Screening Exam (MOMSSE) and UFOV performance were significantly related to crash frequency (r = 0.34 and r = 0.36, respectively), whereas eye health and visual sensory function measures, including visual acuity (r = 0.00), contrast sensitivity (r = 0.10), and visual fields (r = 0.13), did not yield significant results.

This study provided the basis for a larger evaluation of a multilevel model of crash prediction, which required a larger sample and the use of a stratified sampling technique.[13] The recruitment population for this case–control study included all licensed drivers aged 55 years and older living in Jefferson County, Alabama (n = 118,553) as listed in the Alabama Department of Public Safety records. The sampling strategy produced 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 at least one crash in the prior 5-year period to obtain a range for crash involvement that is relatively infrequent in the study population. Three crash frequency categories (0, 1 to 3, 4 or more) and seven age categories were defined (55 to 59, 60 to 64, 65 to 69, 70 to 74, 75 to 79, 80 to 84, and 85+ years). This recruitment strategy yielded a final sample of 294 participants who were involved in 364 at-fault crashes. Results again revealed that visual attention and mental status were related to state-recorded crashes. Of all the measures, UFOV was most strongly correlated with at-fault crashes (r = 0.52), whereas visual acuity and contrast sensitivity were modestly associated with at-fault crashes (r's = 0.225). Structural equation modeling was used to determine which visual and/or cognitive measures had direct effects on the frequency of at-fault crashes. After controlling for eye health and visual function, only UFOV and mental status measures had direct effects on crash frequency.

Useful Field of View and On-Road Driving

Wood and Troutbeck administered a road test on a closed course with various tasks designed to measure peripheral awareness, reaction time, speed estimation, road position, driving time, maneuvering, and reversing to 10 older adults who were all licensed drivers with good ocular health and a distance acuity of 6/6 or better.[24] The mean age of the participants was 64.5 years with a range from 60 to 74 years. Participants were asked to drive under normal conditions and three additional conditions in which goggles simulated the effects of monocularity, cataracts, and binocular visual field restriction. Data analyses identified significant correlations between the total driving score, which was composed of driving performance under all four conditions, and UFOV restriction ($r = 0.55$, $p < 0.005$), and the total driving score and contrast sensitivity ($r = 0.71$, $p < 0.005$). The relationship between the total driving score and visual fields as measured by the Humphrey Field Analyser was not significant ($r = 0.22$).

In a larger study using on-road performance and the UFOV measure, Cushman examined a sample of 123 adults over the age of 55.[25] Ninety-one cognitively intact participants were recruited from the local community, along with 32 patients with early Alzheimer disease (AD). Participants were given a driving questionnaire, a road test knowledge examination, a response time test, vision screening, road skills assessment, and a series of neuropsychological tests including the UFOV assessment. The road test consisted of a progression from low-demand maneuvers in a parking lot to high-demand maneuvers in moderate to heavy traffic. Participants were scored in accordance with the State Road Test Examination (SRTE), which entailed giving error points for error commissions or omissions in performance. They were given a total score indicative of either meeting minimum standards or failing to meet those standards, as dictated by the SRTE. Results indicated that individuals with UFOV reductions >40% had significantly poorer on-road performance than less impaired individuals. Using 40% reduction or greater in UFOV as the cut point for failing the UFOV test, 82% of drivers who failed the UFOV test also failed the road test, and 86% of those who passed the UFOV test passed the road test.

Ducheck and colleagues also conducted a study with healthy controls ($n = 58$) and patients with very mild ($n = 49$) and mild ($n = 29$) AD.[26] All participants were administered the Washington University Road Test (WURT), a 45-min in-traffic road test. The WURT consists of a closed course given in a parking lot and an open course assessing skills such as maintaining speed, obeying traffic signs, signaling, turning, changing lanes, and negotiating intersections. This standardized road test has been found to have acceptable test–retest reliability ($r = 0.76$).[27] All participants were administered a 2-hour psychometric battery consisting of the following tests: Boston Naming Test; Wechsler Memory Scale; Benton Visual Retention Test; Word Fluency Test; Trail Making Test-Part A; and the Information, Block Design, and Digit Symbol subtests of the Wechsler Adult Intelligence Scale–Revised. In addition, a subset of participants was administered the UFOV assessment (28 control subjects, 21 with very mild AD, 6 with mild AD), a visual search task (47 control subjects, 37 with very mild AD, 18 with mild AD), and a visual monitoring task (36 control subjects, 34 with very mild AD, 18 with mild AD). UFOV scores were found to be correlated with driving scores ($r = -.56$), such that greater UFOV reduction was significantly related to poorer driving performance.

Myers and colleagues conducted a study examining the relationship between the UFOV assessment and on-road driving performance in a subsample of 43 patients who were representative of a sample that was comprised of 82% males; 98% whites ranged in age from 61 to 91 years. All of the participants were referred to a driving rehabilitation program.[28] Patients had at least one medical diagnosis, the most common being cerebrovascular accident (CVA). Participants were then given a 13-mile, on-road test covering various driving situations such as secondary roads, a suburban highway, a shopping center parking lot, and downtown traffic. Participants' performance was rated by a certified driving rehabilitation specialist as pass, fail, or questionable. Logistic regression analyses revealed that visual tracking (odds ratio [OR] = 5.87), visual acuity (OR = 2.28), reaction time (OR = 3.53), grooved pegs missed (OR = 3.24), grooved pegs time (OR = 2.62), Hooper Visual Organization Test (OR = 0.34), and UFOV (OR = 13.43) were all significantly correlated to performance on the road test.

Useful Field of View and Driving Simulator Performance

Rizzo and associates conducted a study examining driving simulator performance in older adults with AD.[29] Twenty-one individuals with AD (mean age, 71.5 years) and 18 control subjects (mean age, 71.9 years) without dementia participated in the study. Exclusion criteria included any current incidence of alcoholism, stroke, depression, vestibular disease, or motion sickness. Participants' visual acuity and contrast sensitivity (Pelli-Robson) were assessed as well as their UFOV performance. Participants also navigated a simulated rural two-lane highway in the Iowa Driving Simulator, SIREN. The SIREN is a four-channel, 150° forward view and 50° rear view high-performance simulator that can modify roadway types, pedestrian behavior, and the visual and auditory environments. The simulator course included four events associated with crashes.

Six of the 21 AD participants experienced "crashes" in the driving simulator as compared with none of the control subjects ($p = 0.022$). A series of univariate logistic regression analyses was performed to determine if crashing was associated with cognitive, visual, or demographic measures. Among the 15 participants with total UFOV impairment of 50% loss or greater, six had at least one crash, whereas none of the participants with total UFOV loss <50% had any crashes ($p = 0.002$), including several individuals with AD. Odds ratios revealed that UFOV impairment was an even stronger predictor of simulator crashes than the diagnosis of AD (OR = 18.13 for UFOV; OR = 8.91 for AD).[29]

A study conducted at Western Kentucky University examined the relationship of UFOV performance to driving simulator performance in the context of a larger training study.[30] This study included 104 participants (38 male, 100 white; mean age, 71 years; age range, 55 to 86 years) who were recruited from the surrounding community. On the panel of the simulator, participants watched an array of lights containing six colored blocks. Each of the lights blinked in random order for a duration of 1 second before the simultaneous illumination of two red lights. When the red lights were illuminated, the participant was required to brake as quickly as possible (a simple reaction time task). For the choice reaction time task, participants reacted to four different types of road signs presented on a screen (pedestrian, bicycle, right turn arrow, and left turn arrow). Participants were required to react only to road signs that did not have a red slash through them. For either the bicycle or pedestrian signs, participants responded by braking as quickly as possible. For the turn arrow signs, participants turned the wheel as quickly as possible in the direction that the arrow pointed. Data for both reaction time tasks were recorded as elapsed time in seconds, which can be converted to the distance in feet that a vehicle going 55 mph would have traveled between stimulus onset and participant response. Results of this study identified a significant relationship between UFOV and choice reaction time to varying traffic signs ($r = 0.4220$, $p = 0.0001$) with individuals with greater UFOV impairment demonstrating slower choice reaction times in the driving simulator.

These eight investigations had a combined sample size of 712 adult drivers over the age of 55 years. In an attempt to determine whether the studies could be thought of as coming from the same population, the within-group homogeneity of the effect sizes was tested. The statistic that results from this test is a χ^2 with n -1 degrees of freedom in which n refers to the number of studies referenced.[31] The most common symbol for this statistic is Q, and its value for the eight studies was not statistically significant (Q [7] = 11.29, p [one-tailed] = 0.13), indicating that the samples can be considered homogeneous. Therefore, further combination of the group effect sizes is warranted.[32]

The final weighted, cumulative effect size after adding all eight studies into the analysis was $z' = .60$. Figure 1 reveals that the 95% confidence interval for this effect does not contain 0, signifying that the effect is significantly >0. The combined Fisher's z' of 0.60 is equivalent to an average correlation of 0.535. As a result of the loss in precision when going from a continuous predictor to a dichotomous one, such as impaired UFOV performance versus regular performance, Cohen[33] suggests using a correction to convert the standard r to a point biserial correlation r_p, which equals r/1.253. The point biserial correlation of 0.427 was then converted to Cohen's d, an effect size that is usually used when the means of two groups are compared and represents the difference in those means in standard deviation units ($d = 2r/\text{sqrt}\,[1 - r^2]$). According to Cohen, an effect size of $d = 0.8$ is considered to represent a "large" effect. The effect size yielded by combining these eight studies, $d = 0.945$, was well above Cohen's threshold for a large effect even after the correction was applied. Additionally, the eight studies were subdivided into three categories: studies conducted by individuals with financial interests in the UFOV[13,14,30]; studies in which data were collected and analyzed in independent laboratories that subsequently requested collaboration of UFOV creators during the preparation of manuscripts[26,28,29]; and studies in which the data were collected, analyzed, and reported independently.[24,25] The mean point biserial correlations for these categories were 0.384, 0.493, and 0.485, respectively. When these numbers were converted to Cohen's d, the results were 0.831, 1.133, and 1.109, respectively.

Figure 1 was visually examined to ascertain if a sufficient number of studies have been conducted to conclusively determine that the UFOV assessment is consistently associated with objectively evaluated driving performance in older adults. The confidence interval from step 1 included the final average effect size of all eight studies, so it can be concluded that at no point in the cumulative data analysis would the population effect size be expected to be any different from the final average effect size. This crude manner of measuring sufficiency can be used as an initial step in determining the need for additional research to establish a phenomenon.[34] A more concrete measure of sufficiency was examined by using the BASIC meta-analysis software to calculate the failsafe number.[35] This unweighted procedure revealed that an additional 513 studies that averaged a null result must be conducted to bring the p value for the cumulative effect size to be > 0.05. In other words, many null findings would be necessary to negate the result of this meta-analysis. Finally, the mean effect size at each wave varied only slightly, suggesting stability across studies conducted at different points in time by different research teams.

DISCUSSION

The data present a relatively clear picture: poorer UFOV test performance is associated with poor driving performance in older adults. The effect size obtained when the UFOV assessment was correlated with objective driving performance is large compared with standard assessments of visual acuity, other visual sensory functions, and various cognitive domains.[14,36] This highlights the use of higher-order visual–cognitive processes in predicting driving performance. The consistency of the relationship between UFOV and driving has been discussed in several related review articles[37]; the current meta-analysis serves as quantitative confirmation of this relationship.

With regard to the relationship between UFOV test performance and driving, it is noteworthy that the relationship is robust across multiple indices of driving performance and several research laboratories. In this review, we examined studies using as performance criteria state-recorded crash records, on-road driving, and driving simulator performance. The relationship between UFOV performance and driving competence was strong for all outcome measures. This convergence of evidence across numerous studies using different methodologies strongly suggests that the UFOV assessment is a valid and reliable index of driving performance and safety. Additionally, the selection of only one effect per protocol (i.e., only one study using a given sample) diminishes the potential to overweight studies with positive findings.

Other reports have examined the relationship between measures of attention/concentration and driving performance. Reger and associates performed a meta-analysis that examined UFOV, Trails A, Digit Span, Digit Symbol, and other measures to show their ability to predict driving performance.[38] Their analysis was restricted to studies of participants with dementia, and studies included in their analysis included less objective measures of driving performance such as tests of driving knowledge and caregivers' reports of driving ability. If more than one measure of attention and concentration was reported in the same study, Reger and associates combined the effects and included them in their final results. The selection of only demented patients and the combination of UFOV with less effective predictors of driving performance may account for the smaller uncorrected mean effect sizes found in their investigation, r = .48 for on-road tests and r = .35 for nonroad tests.

The strong association between UFOV performance and retrospective crashes[13] led to a supplemental investigation of the same age- and crash-stratified sample of 294 older drivers to evaluate UFOV as a predictor of prospective crash involvement.[39] Crash records were collected for the 3 years after the single clinic visit completed by each participant. Visual acuity, contrast sensitivity, stereoacuity, disability glare, visual field sensitivity, and a 40% reduction in UFOV were each examined as potential predictors of crash rate, which was measured in terms of crashes per million person-miles of travel. UFOV was a significant predictor of crash rate from bivariate analysis, and when adjusted for age, sex, race, mental status, and chronic medical conditions, individuals with a 40% reduction in UFOV were 2.2 times more likely to be involved in a crash.[39] This investigation specifically evaluated the predictive use of the UFOV and does not negate the potential importance of other measures of higher cognitive processing or visual information processing.

The evidence of a relationship between UFOV test performance and driving performance has far-reaching implications for public policy. One potential practical application of these findings would be the use of the UFOV assessment as a screening instrument to determine the need for further assessment of driving ability. For example, if a physically healthy individual over 65 years of age has a completely unrestricted UFOV, the chances of that individual failing a road test may be so small that it may not be worth the cost and effort required to administer the road test. Further research is needed to determine reliable UFOV cutoff scores that might indicate the need for a further driving assessment. If a screening battery incorporating the UFOV assessment were widely adopted by state departments of motor vehicles, then drivers with identified risk could potentially be referred for appropriate interventions to restore safe mobility. There is now a growing body of literature indicating that visual processing speed can be improved through training and that such training results in improved driving safety and other indices of mobility.[30,40]

An initial field study has been completed that evaluated the UFOV test as a potential screening instrument. A population-based study recently assessed older adults coming in to renew their driver's licenses in three motor vehicle administration (MVA) field site offices in the state of Maryland. A total of 2114 elders agreed to assist in the evaluation of a series of screening measures. The screening battery was designed to be brief; therefore, only subtest 2 of the UFOV test was included (among the three subtests of the UFOV, subtest 2 has been found to have the highest correlation with at-fault crashes).[38] An analysis of at-fault crashes in the 2.5 years after assessment (adjusted for driving exposure) showed that individuals with poor UFOV performance were over two times as likely to be involved in an at-fault crash.[41] These prospective results, which are based on a primarily unimpaired sample of licensed drivers, reinforce the retrospective and concurrent results presented in this meta-analysis. Results are consistent with the position that poor UFOV performance, associated with either poor visual sensory function, AD, stroke, or simply increasing age, is a significant indicator of crash risk. Additional prospective, longitudinal studies are needed to investigate potential differences in the predictive power of the UFOV in samples with early dementia, medical impairments such as stroke, and samples of community-dwelling older adults.

The Maryland MVA has outlined goals to evaluate the effectiveness of its Older Driver Program.[42] The ability of such a program to proactively identify at-risk older drivers could impact policy decisions nationwide. Their objectives include: changing existing public perceptions of older driver competency, shifting the focus from driving cessation to maintaining independence, helping aging drivers and their families prepare for the transition through stages of driving cessation, and promoting alternative transportation resources as aging drivers become unable to remain independent through driving.[42] Their belief is that keeping our seniors mobile allows them to continue to contribute to our economy, which would, in turn, avoid a significant financial loss. They also propose that additional new revenue business streams will be created for hospitals and/or clinics with occupational therapy rehabilitation specialists and for certified professional driving schools through the identification of older drivers who need remediation.

In summary, the current cumulative meta-analysis revealed that a sufficient number of studies have been conducted to conclusively demonstrate that the UFOV test is a valid indicator of retrospective and concurrent driving performance in older adults. Although performance on the UFOV does not provide information in terms of what the underlying causes of visual information processing failures might be, it does represents a final common pathway of higher visual and cognitive impairment. Furthermore, the effectiveness of the UFOV measure as a predictor of incident crashes and as a screen for detecting at-risk older drivers corroborates our results. The remaining step is to apply this knowledge base in a reasonable and concise manner as a means of increasing the viability and safety of older adults who continue to drive.

Received December 1, 2004; accepted March 2, 2005.

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