4-2012

Useful Field of View Predicts Driving in the Presence of Distracters

Joanne M. Wood
Queensland University of Technology

Alex Chaparro
Wichita State University, chapara3@erau.edu

Philippe Lacherez
Queensland University of Technology

Louise Hickson
University of Queensland

1040-5488/12/8904-0373/0 VOL. 89, NO. 4, PP. 373–381
OPTOMETRY AND VISION SCIENCE

FEATURE ARTICLE ON LINE

Useful Field of View Predicts Driving in the Presence of Distracters

Joanne M. Wood*, Alex Chaparro†, Philippe Lacherez†, and Louise Hickson†

ABSTRACT

Purpose. The Useful Field of View (UFOV®) test has been shown to be highly effective in predicting crash risk among older adults. An important question which we examined in this study is whether this association is due to the ability of the UFOV to predict difficulties in attention-demanding driving situations that involve either visual or auditory distracters.

Methods. Participants included 92 community-living adults (mean age 73.6 ± 5.4 years; range 65–88 years) who completed all three subtests of the UFOV involving assessment of visual processing speed (subtest 1), divided attention (subtest 2), and selective attention (subtest 3); driving safety risk was also classified using the UFOV scoring system. Driving performance was assessed separately on a closed-road circuit while driving under three conditions: no distracters, visual distracters, and auditory distracters. Driving outcome measures included road sign recognition, hazard detection, gap perception, time to complete the course, and performance on the distracter tasks.

Results. Those rated as safe on the UFOV (safety rating categories 1 and 2), as well as those responding faster than the recommended cut-off on the selective attention subtest (350 msec), performed significantly better in terms of overall driving performance and also experienced less interference from distracters. Of the three UFOV subtests, the selective attention subtest best predicted overall driving performance in the presence of distracters.

Conclusions. Older adults who were rated as higher risk on the UFOV, particularly on the selective attention subtest, demonstrated poorest driving performance in the presence of distracters. This finding suggests that the selective attention subtest of the UFOV may be differentially more effective in predicting driving difficulties in situations of divided attention which are commonly associated with crashes.
(Optom Vis Sci 2012;89:373–381)

Key Words: useful field of view (UFOV), driving, distracters, selective attention, older drivers

The Useful Field of View (UFOV) has been the focus of a large body of research which has demonstrated that the test can reliably predict a number of adverse driving outcomes among older adults with and without ocular disease.[1] Poorer performance on the UFOV is a strong predictor of both retrospective[2,3] and prospective crashes[4–6] in general populations of older adults as well as in those with ocular disease.[7] Studies have also reported strong associations between poorer UFOV scores and unsafe performance as determined by on-road assessments[8,9] and driving simulators.[10] The predictive ability of the UFOV has been shown to extend to older individuals with a range of systemic conditions including stroke,[11] Parkinson's disease,[12] and dementia.[13,14]

*PhD, FAAO
†PhD
School of Optometry and Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Queensland, Australia (JMW, PL), Department of Psychology, Wichita State University, Wichita, Kansas (AC), and School of Health and Rehabilitation Sciences, Communication Disability Centre, University of Queensland, Brisbane, Queensland, Australia (LH).

To better understand these associations between performance on the UFOV and indices of driving performance, it would be useful to better clarify the mechanisms that the test taps into and determine how these relate to adverse driving outcomes. It is generally considered that the test measures the extent of useful visual function (that can be seen and attended to) by virtue of an implicit trade-off between accurate perception of visual stimuli presented peripherally, rapidly, or with low salience.[2,15,16] Thus, the test measures the presentation time at which stimuli can be detected better than chance (at 75% accuracy) under varying conditions of salience: (1) when presented centrally and in isolation, (2) when presented in pairs, with one stimulus presented centrally and one peripherally—known as "divided attention," and (3) when presented in pairs, together with irrelevant distracters—known as "selective attention."[2,15]

As the focus of the test is to assess the response latency for detection of peripheral stimuli when visual salience is manipulated by increasing task complexity (i.e., from a single task to a dual task with distracters), it is likely that the test taps into several domains of visual perceptual and cognitive function which are relevant to drivers. Given that the literature suggests that the majority of motor vehicle collisions may be the result of inattention caused by increased distractibility[17] and evidence shows that older adults are particularly vulnerable to the effects of distraction,[18,19] we hypothesize that the factor of distractibility in particular may be a key component of the success of this test. That is, performance on the divided and selective attention components of the UFOV may be particularly related to distractibility in older adults, which then relates to their performance at times when a number of objects of importance must be attended to—situations which have been found to be problematic for older drivers.[1] The fact that driving is a complex activity that presents particular challenges for some older adults is evidenced by the relatively high crash rates of older drivers who are more likely than younger drivers to be involved in multi-vehicle crashes in complex traffic conditions and at intersections.[20,21] This propensity for having problems in more complex environments is highly relevant, given that the driving environment, as well as that of modern vehicles, is becoming increasingly complex, which can impose an increased mental workload on older drivers in particular.[22] Vehicles are now commonly instrumented with sophisticated navigation and entertainment systems which, like mobile phones, may add to the driver's attentional burden, distracting them from the primary driving task.

In line with this, recent research has highlighted the potential impact of increased distraction while driving, particularly for auditory distractions and mobile phone use.[23–26] Attending to auditory information has been shown to impair performance on concurrent cognitive as well as motor tasks, and the degree of this interference varies as a function of the effort required by the secondary task.[27–29] In addition, even in the absence of distracters within the in-vehicle environment, there are specific driving situations (such as complex intersections or road work sites) that place competing demands on multiple sensory and cognitive abilities, often simultaneously.

In this study, we examined the relationship between the outcome measures of the UFOV and real-world measures of driving performance conducted in the presence of visual and auditory distracters to make the level of complexity more representative of everyday driving tasks. We hypothesized that the UFOV should capture aspects of driving under more complex situations, such as driving in the presence of a secondary task, and that the selective attention subtest would be the best predictor of these aspects of driving performance. This hypothesis is grounded in the assumption that the skills that underlie selective attention, such as the switching and focusing of attention, are also critical to driving. Support for this hypothesis is offered by studies showing that among the alternative measures of attentional capacity (i.e., divided, selective, and sustained attention), selective attention is most strongly associated with motor vehicle crashes, particularly in those with early dementia,[30–32] and we recently demonstrated that a timed selective attention test was the best predictor of driver errors in a group of community-dwelling older drivers.[33]

METHODS

Participants

Participants included 92 older drivers (mean age = 73.6 ± 5.4 years; range 65–88 years; 50 males and 42 females) who were recruited from the University of Queensland 50+ Research Register, staff at Queensland University of Technology, and the wider community. The study protocol was in accord with the declaration of Helsinki and was conducted in accordance with the requirements of the Queensland University of Technology Human Research Ethics Committee. All participants were given a full explanation of the experimental procedures, and written informed consent was obtained with the option to withdraw from the study at any time.

All participants lived in the community, were licensed drivers, and met the minimum Australian drivers' licensing criteria of binocular visual acuity of 6/12 (20/40) or better. Participants with a clinical history of ocular or systemic disease associated with visual field loss were not included.

Participants reported a range of driving experiences. On average, they drove 5 days per week (SD = 1.7; range = 1–7). The majority (74%) had more than 50 years of driving experience; 19.5% had 41 to 50 years experience and the remainder (6.5%) had between 20 and 40 years of experience. Seventy-two percent drove more than 60 km per week. Participants reported an average of one crash per 25 driver years. Sixteen percent of participants reported that they wore a hearing aid in one or both ears when driving. The majority of participants had completed secondary (39%) or tertiary education (38%), with only 23% finishing school at primary level. The Mini-Mental State Examination was used to provide an indication of general cognitive function, and all but two participants scored at or above the criterion level of 23 (mean = 28.5; SD = 1.7; range = 21–30).

Measures

Participants attended two testing sessions, the first of which was a laboratory session where demographic information was collected along with assessment of vision, cognition, and hearing. The second session involved assessment of driving performance on a closed-road circuit. The focus of this article is on the assessment of the UFOV; data relating to other components of the study have been reported elsewhere for a larger sample that included the participants in this study and demonstrated significant effects of age and hearing impairment on the driving outcome measures.[34]

Visual acuity and letter contrast sensitivity were measured binocularly wearing the optical correction participants normally wore while driving, if any. Static visual acuity was assessed using a high-contrast Bailey-Lovie chart at a working distance of 6 m and letter contrast sensitivity measured with a Pelli-Robson chart at a working distance of 1 m as recommended.

Useful Field of View

Participants completed all three subtests of the commercially available UFOV® version 6.0.8 following the procedures recommended in the testing manual.[16] This computer-based test measures visual processing speed for three subtests which involve attentional tasks of increasing difficulty. The task was administered binocularly and participants were given the opportunity to practice each of the UFOV tasks.

Subtest 1 (visual processing speed) is a central discrimination task and requires the participant to identify a high-contrast target (outline of a car or a truck 18 mm × 13 mm) presented centrally within a 30 mm × 30 mm demarcation box while the stimulus duration is varied according to the participant's responses. Subtest 2 (divided attention) consists of the central discrimination task described for subtest 1; however, the participant is also required to localize a second high-contrast target presented peripherally. These targets are presented randomly in one of eight locations along eight radial spokes (location from the upper vertical: 0°, 45°, 90°, 135°, 180°, 225°, 270°, or 315°) at a peripheral eccentricity of 10°. Subtest 3 (selective attention) involves the same tasks as in subtests 1 and 2 with the addition of distracter targets. These consist of an array of inverted triangles of the same size and contrast as the peripheral targets. A threshold score (given in milliseconds) for processing time is calculated for each of the three subtests dependent on participant responses. In addition, a composite of all scores is calculated automatically and assigns participants a safety rating category ranging from 1 "very low risk" to 5 "high/very high risk."

Driving

Driving performance was assessed on a 4 km section of a closed-road circuit which contains a number of hills, curves, and intersections and is representative of a rural road. In the interests of safety, the circuit was free of other vehicles (except for a second car which followed behind the experimental vehicle so that the experimenters could reposition hazards and change cone gap widths between measurement runs). Participants drove a right hand drive sedan (1997 Nissan Maxima) with an automatic transmission and power steering. If participants normally wore glasses and/or hearing aids while driving, they wore these during the assessment. Participants were given a practice run during which they were able to familiarize themselves with the car, the road circuit, and the driving tasks. The practice run was identical to each test run except that it was driven in the opposite direction to the recorded runs so as to minimize familiarity effects. It included driving without distraction and then with the visual and auditory distracters added separately, so that participants had the opportunity to practice all components of the assessment before the recorded runs. Participants were instructed that they would be required to perform a number of concurrent tasks while driving at what they felt was a safe speed, to drive in their own lane except when avoiding hazards, and to drive as they normally would under the circumstances. Performance was recorded by two experimenters, one seated in the passenger seat of the vehicle and the other in the rear seat, who recorded different aspects of the driving assessment. To establish the reliability of these measures, two raters independently scored one of the driving measures in a random sample of 20 participants and revealed an inter-rater reliability of r = 0.99.[34]

Time to Complete the Road Course

An experimenter in the vehicle recorded the total time taken to complete the circuit.

Road Sign Recognition

The road sign recognition task required participants to report the information on any of 54 road signs located along the course (e.g., stop, give way) containing a total of 77 items of information. A participant's score represented the total number of correctly reported items of information.

Road Hazard Recognition and Avoidance

Participants were required to report and avoid hitting any of nine large, low-contrast foam rubber road hazards that were centered across the driving lane. The road hazards were constructed from sheets of 180 cm × 80 cm × 5 cm gray/brown foam rubber with a mean reflectance of 10%. Although the hazards could be felt when driven over, they had little effect on vehicle control. The position of the road hazards was randomized between each lap; during any given trial, only 9 of a total of 11 hazards were positioned on the course. Performance was measured as the number of road hazards hit.

Gap Perception

Nine pairs of traffic cones with variable lateral separations were also positioned throughout the course. Equal numbers of cones were set to be not wide enough, just wide enough, and obviously wide enough for the test vehicle to pass through. Participants were instructed to report whether the clearance between cones was sufficient for the vehicle to pass through and, if so, to attempt to do so. If the cone separation was judged to be too narrow, the participants were instructed to drive around the cones. The separation of the cones was varied between each lap. Performance was measured as the number of cone gaps judged correctly.

Composite Driving Z Score

A composite score was also derived to capture the overall driving performance of the individual participants compared with the whole group and included road sign recognition, cone gap perception, course time, and the number of road hazards hit as per our previous studies.[9,35,36] Z scores for each of these four component driving measures were determined and the mean Z score for each participant was calculated to give an overall score. Equal weighting was assigned for all tasks.

Participants drove around the track three times: (1) without distraction, (2) with visual distraction, and (3) with auditory distraction. The order of conditions was randomized between participants. The distraction task required participants to verbally report the sums of single-digit numbers presented either via a dashboard-mounted LCD monitor (visual distracter) or through a computer speaker (auditory distracter) while driving.[34–36] The monitor was positioned just to the left of the steering wheel on the dashboard, slightly below driver eye height. The visual task consisted of the simultaneous presentation of pairs of numbers (e.g., 1 + 5) subtending between 3.5° and 4.8° of visual angle at the viewing distance of participants. The auditory stimuli were presented at a comfortable and easily audible listening level that was individually set for each participant. Pairs of numbers were presented every 3.5

sec. Performance measures for the distracter tasks included the percentage of correct responses and the percentage of missed responses.

Data Analysis

To determine which of the three subtest measures of the UFOV or the overall UFOV safety rating were best related to driving performance, bivariate correlations among the three UFOV subtests, the overall UFOV safety rating risk score, and the driving Z score were examined for each of the separate driving runs (baseline, visual, and auditory distracters), as well as an overall score across all the three driving conditions. To examine the influence of the visual and auditory distracters on driving performance, as a function of participants' UFOV safety rating, a series of mixed factorial analyses of variance (ANOVA) were conducted with the within-subjects factor of distracter condition (none, visual, or auditory) and between-subjects factor of UFOV performance. To test whether the relationships with UFOV performance interacted with the effects of age and hearing acuity that we presented previously,[34] analyses were also conducted using age and hearing acuity as covariates. These analyses did not reveal any significant higher order interactions and therefore are not reported here. Analyses were also conducted on the summing task (visual vs. auditory) as a function of UFOV performance. Subjects were categorized into two groups in terms of their overall UFOV safety rating, as there were too few participants in some of the UFOV categories to enable analysis (in particular only seven participants were rated in category 4 "moderate to high risk" and only one in category 5 "very high risk"). The groups consisted of those rated "low risk" (categories 1 and 2, n = 72) vs. all other categories (categories 3–5, n = 20) representing "moderate to high risk." Further analyses were conducted separating participants into groups based on their performance on subtests 2 and 3 using the cut-offs recommended in the UFOV User Manual (>100 and >350 msec, respectively)[16] as well as an alternative cut-off of >150 msec for subtest 2 which has previously been reported to represent "poor" UFOV performance.[37] As the assumption of sphericity was violated in some instances, the tests were performed using multivariate tests of significance which do not require sphericity.[38]

RESULTS

The demographic and visual characteristics of the participants are given in Table 1. All participants had normal levels of visual acuity and contrast sensitivity for age.

Table 2 gives the bivariate correlations between the overall UFOV safety rating and the three subtest measures of the UFOV and overall driving Z score and then individually for driving performance in the no distracter condition as well as driving performance in the presence of visual or auditory distracters. The subtest 3 selective attention component was most highly correlated with overall driving score calculated for performance over the three driving runs.

A 2 × 3 mixed ANOVA with the factors of UFOV safety rating (with two levels: low vs. high risk) and distraction (none, visual, or auditory) on the overall driving Z scores revealed a main effect of distraction, $F(2,89) = 7.33$, $p < 0.001$. Overall performance was better in the no distracter condition than in either of the two distracter conditions; however, there was no significant difference between the visual and auditory distracter conditions. There was also a significant main effect of UFOV safety rating, $F(1,90) = 7.07$, $p = 0.009$, where those with a poorer safety rating had significantly poorer overall driving scores (assessed across the three conditions). There was no significant two-way interaction between safety rating and distracter condition for the overall driving Z score.

TABLE 1.
Demographic characteristics of the participants and their performance on the vision tests and the UFOV

	Count (%)	N	Mean (SD)	Range
Age		92	73.59 (5.44)	65–88
Gender				
Male	50 (54%)			
Female	42 (46%)			
Bailey-Lovie binocular VA		92	0.01 (0.09)	−0.18 to 0.26
Pelli-Robson binocular CS		92	1.69 (0.12)	1.45–1.95
UFOV subtest 1 processing speed		92	22.13 (13.29)	16.7–89.9
UFOV subtest 2 divided attention		92	110.78 (105.15)	16.7–500
Safe ≤100 msec	53 (58%)			
Unsafe >100 msec	39 (42%)			
UFOV subtest 3 selective attention		92	262.32 (121.66)	36.6–500
Safe ≤350 msec	72 (78%)			
Unsafe >350 msec	20 (22%)			
UFOV safety rating				
1.00 very low risk	44 (48%)			
2.00 low risk	28 (30%)			
3.00 low to moderate risk	12 (13%)			
4.00 moderate to high risk	7 (8%)			
5.00 high/very high risk	1 (1%)	92		

Two-way ANOVAs conducted on the individual driving measures revealed a significant main effect of distraction upon the overall time to complete the course, $F(2,89) = 9.05$, $p < 0.001$, and for sign recognition, $F(2,89) = 28.95$, $p < 0.001$, but not for hazard detection or gap perception. The time to complete the course was longer in the visual condition than in either the auditory or no distracter condition (i.e., drivers slowed down significantly in the visual distracter condition): the auditory and no distracter conditions did not differ significantly from one another. More road signs were recognized in the no distracter condition than in either the visual or auditory conditions, with the least number of signs recognized in the auditory condition (all pairwise differences were significant). Overall, participants made more correct responses, $F(1,88) = 8.38$, $p = 0.005$, and missed less trials on the summing task, $F(1,102) = 3.02$, $p = 0.086$, in the visual than in the auditory condition. There were also significant two-way interactions between distraction and UFOV safety rating for time to complete the course, $F(2,89) = 8.02$, $p = 0.001$, and sign recognition, $F(2,89) = 4.63$, $p = 0.012$. Figs. 1 and 2 represent these two-way interactions. Participants rated as unsafe by the UFOV safety rating took longer to complete the course in the visual condition than in either the auditory or no distracter condition, while the auditory and no distracter conditions did not differ significantly from each other. For those rated as safe, however, there was no effect of distracters on time to complete the course. Both groups recognized more signs in the no distracter condition than in either of the two distracter conditions, and there were also significantly fewer signs read in the auditory than in the visual distracter condition for those rated unsafe but not for those rated as safe.

A series of two-way ANOVAs were also conducted contrasting those who scored above the recommended cut-offs for the UFOV subtests 2 and 3 (>100 or >150 msecs for subtest 2, n = 39 and n = 26, respectively, and >350 msec for subtest 3, n = 20) vs. those who scored below the cut-offs. There were no significant main effects or interactions observed for the UFOV subtest 2 on any of the performance measures for either cut-off level. There was a significant main effect, however, for UFOV subtest 3 (with a cut-off of >350 msec) for the overall driving performance score, where those classified as unsafe had lower overall driving scores, $F(2,90) = 4.93$, $p = 0.029$. There was also a significant two-way interaction between the UFOV subtest 3 and distraction for time to complete the course, $F(2,89) = 6.85$, $p = 0.002$, which is represented in Fig. 3. For those rated safe on UFOV

TABLE 2.
Correlations between UFOV performance measures and overall driving score both overall and within each of the distracter conditions

UFOV outcome measure	Driving performance: Overall score	Baseline	Visual distracter	Auditory distracter
UFOV safety rating	−0.243[a]	−0.207[a]	−0.234[a]	−0.167
UFOV test 1: processing speed	−0.184	−0.153	−0.172	−0.135
UFOV test 2: divided attention	−0.256[a]	−0.258[a]	−0.203	−0.181
UFOV test 3: selective attention	−0.293[b]	−0.259[a]	−0.215[a]	−0.257[a]

[a] $p < 0.05$.
[b] $p < 0.01$.

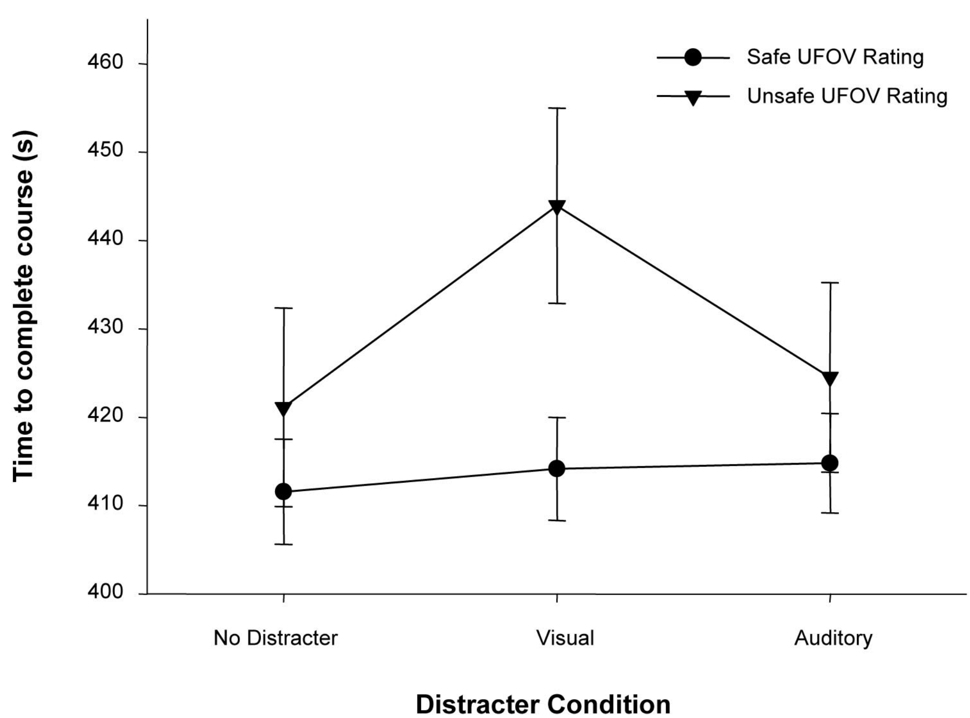

FIGURE 1.
Interactive effect of distracter condition and UFOV safety category on time to complete the course.

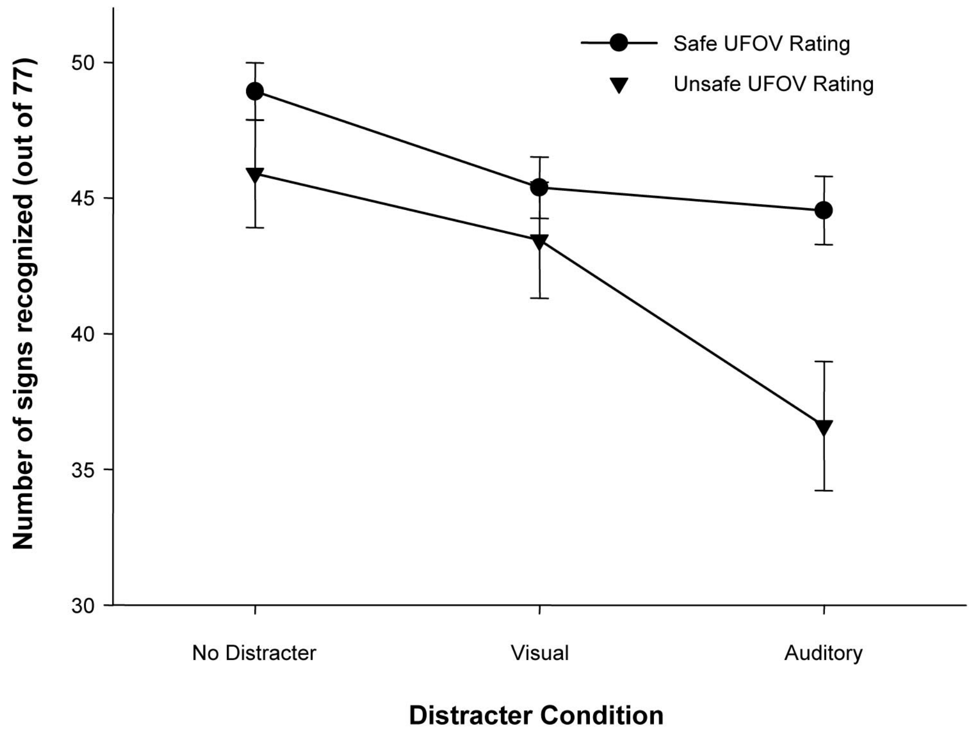

FIGURE 2.
Interactive effect of distracter condition and UFOV safety category on number of signs recognized.

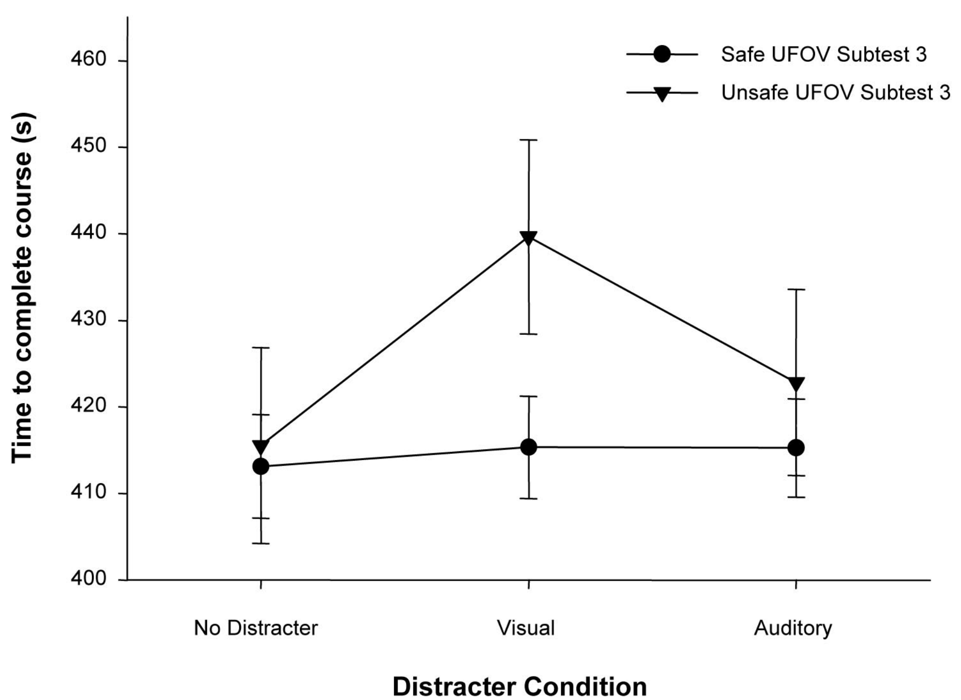

FIGURE 3.
Interactive effect of distracter condition and performance on the selective attention UFOV subtest 3 on time to complete the course.

subtest 3, there were no significant differences between the three conditions, while those rated as unsafe took significantly longer to complete the course in the visual distracter condition than in either the no distracter or auditory distracter conditions; the no distracter and auditory distracter conditions did not differ significantly. Participants who performed worse on the UFOV subtest 3 also made less correct responses, $F(1,88) = 7.6$, $p = 0.007$, and had more missed trials on the summing task, $F(1,88) = 8.67$, $p = 0.004$. However, there was no significant interaction between UFOV performance category and distracter modality.

DISCUSSION

The findings demonstrate that the UFOV significantly predicted driving performance both in the presence and absence of visual or auditory distracters. Moreover, the UFOV scores predicted interference in the distracter conditions such that those who were scored as safe experienced less decrement in driving performance in the presence of distracters than those scored as unsafe. This finding suggests that the driving problems elicited in the presence of visual or auditory distracters are greatest for those who are rated most at risk for crashing overall.

Collectively, these findings are important in terms of better understanding the mechanisms of impaired driving in older adults. The finding that greater distractibility as evidenced in simple, laboratory measures of divided and selective visual attention also predict the ability to drive safely in the presence of distracters provides a basis for predicting those who will be more distractible on the road and therefore also those who might benefit from minimizing distraction while driving.

In particular, the differences in time to complete the course are likely to reflect changes in driving speed choices which have been widely observed in the older driver literature.[39–42] Older drivers typically drive slower, possibly in an effort to better allocate their attention and monitor what is on the road ahead, because they perceive it to be safer to drive more slowly or because they lack confidence in their response times at high speeds. However, driving more slowly is not guaranteed to reduce crash rates and indeed could lead to traffic conflicts as other drivers endeavor to maneuver around slower vehicles. In our sample, it is clear that increases in attentional load led to changes in driving speed which may reflect moment-by-moment changes in confidence in maintaining safe driving behavior; i.e., the older drivers self-regulate their driving speed in an attempt to compensate for their reduced ability to maintain concentration on the road. Moreover, this change in speed was significantly greater for those who exhibited poorer scores on the selective attention test. These findings are consistent with a recent study which demonstrated that older adults slowed down under a range of challenging driving conditions in a driving simulator and that those scoring more poorly on the divided and selective attention subtests of the UFOV reduced their speed more under these conditions.[43]

With regard to reading road signs, this is likely to involve some level of phonological interference as both the reading task and the distracter (sums) task involve some phonological component as we have reported elsewhere.[34] This is supported by the finding that the auditory distracter produced as much interference as the visual distracters (indeed slightly greater). Nonetheless, the interference caused in this activity is reliably predicted in this sample of older drivers by the UFOV, a test of visual awareness and attention, which is unrelated to phonological coding ability. Traditional models of dual task interference suggest that the visuospatial and phonological working memory resources are largely independent of one another, which is usually interpreted to suggest that visual interference and phonological interference have separate effects.[44,45] Thus, the finding that the UFOV predicts interference even by auditory distracters lends further support to the notion that it may serve as a more general test of distractibility—in addition to a more specific test of visual awareness—for this population.

It is also possible that the sign reading task may have been given a lower priority in the presence of auditory distracters, due to their transitory nature, indicating a trade-off in performance between these cognitively challenging tasks. This might be expected to be the case, particularly for those rated as unsafe on the UFOV. However, the data showed no evidence of such a trade-off. Participants rated as unsafe on the UFOV performed worse on both the driving and summing tasks, and all participants performed worse on the auditory than visual distracter tasks, mirroring the relative decline in performance on the driving tasks.

The finding that the selective attention component of the UFOV is the subtest most predictive of driving performance under more complex driving conditions is not unexpected given the complexity of driving and the need to focus attention on important and salient objects when there are numerous other features within the road environment. This finding concurs with those of Haymes et al.[7] that the strongest risk factor for motor vehicle crashes in patients with glaucoma was impaired UFOV selective attention. Similarly, Pietras et al.[46] showed that older drivers with specific declines in selective attention made more unsafe traffic-entry judgments than older drivers with normal levels of attention, including shorter time-to-contact estimates, longer times to cross the roadway, and shorter safety cushions (the difference between time-to-contact and time-to-cross the roadway). Simulations showed that these performance differences increased the crash risk of the impaired group by up to 17.9 times that of the nonimpaired group. Chaparro et al.[47] also found that the UFOV selective attention subtest was the better predictor of both crashes and the ability to detect and react to hazards in a driving simulator.

Previous studies have demonstrated that crash risk is best predicted by the divided attention component of the UFOV[4,6,48]; however, these studies have not looked specifically at crashes occurring under complex situations. It is possible that for those crashes which are the result of excessive latency, or inability to see and respond to hazards in complex environments (e.g., intersections or complex merging situations), divided attention may be the superior predictor. However, for those situations which require selectively attending to the task of driving while simultaneously ignoring an irrelevant distracter (e.g., radio, conversation, or other distracting noise in the environment), selective attention may be the more important correlate. It is also possible that with a lower functioning cohort, including those with visual impairment or early cognitive impairment, the divided attention component may be more discriminating than observed here, as reported by other authors.[4] Alternatively, the choice of cut-off levels may also impact on the relative importance of the UFOV subtests in predicting driving outcomes. However, in our study, we found that the choice of cut-off for subtest 2 (either >100 or >150 msec) did not affect the outcomes. In addition, while Ball et al.[48] suggested a cut-off of 300 msec for subtest 2, this cut-off would have resulted in only seven drivers being scored as unsafe in our sample of community-dwelling older drivers with normal levels of vision and cognition.

In terms of the use of the UFOV in research, some researchers have used only the divided attention subtest of the UFOV in predictive models.[4,48] Our data suggest that such a strategy may exclude potentially valuable information, as the selective attention subtest may also correlate with driving difficulties, especially those manifested by difficulties involving ignoring an irrelevant distracter. This makes sense because efficient performance under complex conditions requires that drivers restrict attention to goal-relevant information and suppress other salient but irrelevant stimuli. The inhibitory processes suppress irrelevant, non–goal-related information (e.g., the distracters in visual search), preventing such irrelevant information from drawing attention away from the primary task. The susceptibility of older adults to various type of distraction may be due to structural and volumetric changes in the prefrontal cortex[49] and in subcortical areas (e.g., putamen, basal ganglia)[50] which are known to play a role in inhibitory processes and attention.

Our findings that the UFOV test relates to driving performance in the presence of both visual and auditory distracters should be considered in light of some potential study limitations. In particular, while participants were driving under more realistic conditions than, for example, in a simulator, the circuit was free of other vehicles. Future research should investigate performance under conditions that recreate more of the complexities of driving including interactions with other traffic, moving hazards, and negotiating intersections in traffic. Based on our findings using standardized distracter tasks, it would also be useful to include other types of distractions such as mobile phones, satellite navigation, and different levels of traffic complexity.

Our results have important implications for the design of in-vehicle devices, such as satellite navigation devices and mobile phones (even when hands free). The effects of distracters are likely to be exacerbated as the driving environment becomes increasingly complex. There is compelling evidence that older drivers have more crashes in complex situations and environments, including intersections and yielding right of way,[51] which is likely to be linked to their inability to focus on relevant information while inhibiting irrelevant information within the driving environment. Our findings are also important in terms of the functional use of the UFOV for informing older drivers of their abilities and restrictions, suggesting that older drivers who exhibit lower performance on the selective attention subtest in particular should be advised to minimize unnecessary distraction while driving.

ACKNOWLEDGMENTS

The authors thank the QUT Vision and Driving team for assistance in data collection, the Mt. Cotton Driver Training Centre (Transport and Main Roads), and all the participants for their time.

The research was supported by an Australian Research Council Discovery grant and by participants from the 50+ Registry of the Australasian Centre on Ageing, The University of Queensland.

Received August 11, 2011; accepted December 22, 2011.

REFERENCES

1. Clay OJ, Wadley VG, Edwards JD, Roth DL, Roenker DL, Ball KK. Cumulative meta-analysis of the relationship between useful field of view and driving performance in older adults: current and future implications. Optom Vis Sci 2005;82:724–31.
2. Ball K, Owsley C, Sloane ME, Roenker DL, Bruni JR. Visual attention problems as a predictor of vehicle crashes in older drivers. Invest Ophthalmol Vis Sci 1993;34:3110–23.
3. Owsley C, Ball K, Sloane ME, Roenker DL, Bruni JR. Visual/cognitive correlates of vehicle accidents in older drivers. Psychol Aging 1991;6:403–15.
4. Owsley C, Ball K, McGwin G, Sloane ME, Roenker DL, White MF, Overley ET. Visual processing impairment and risk of motor vehicle crash among older adults. JAMA 1998;279:1083–8.
5. Cross JM, McGwin G, Jr., Rubin GS, Ball KK, West SK, Roenker DL, Owsley C. Visual and medical risk factors for motor vehicle collision involvement among older drivers. Br J Ophthalmol 2009;93:400–4.
6. Rubin GS, Ng ES, Bandeen-Roche K, Keyl PM, Freeman EE, West SK. A prospective, population-based study of the role of visual impairment in motor vehicle crashes among older drivers: the SEE study. Invest Ophthalmol Vis Sci 2007;48:1483–91.
7. Haymes SA, Leblanc RP, Nicolela MT, Chiasson LA, Chauhan BC. Risk of falls and motor vehicle collisions in glaucoma. Invest Ophthalmol Vis Sci 2007;48:1149–55.
8. Myers RS, Ball KK, Kalina TD, Roth DL, Goode KT. Relation of useful field of view and other screening tests to on-road driving performance. Percept Mot Skills 2000;91:279–90.
9. Wood JM. Age and visual impairment decrease driving performance as measured on a closed-road circuit. Hum Factors 2002;44:482–94.
10. Roenker DL, Cissell GM, Ball KK, Wadley VG, Edwards JD. Speed-of-processing and driving simulator training result in improved driving performance. Hum Factors 2003;45:218–33.
11. George S, Crotty M. Establishing criterion validity of the Useful Field of View assessment and Stroke Drivers' Screening Assessment: comparison to the result of on-road assessment. Am J Occup Ther 2010;64:114–22.
12. Classen S, McCarthy DP, Shechtman O, Awadzi KD, Lanford DN, Okun MS, Rodriguez RL, Romrell J, Bridges S, Kluger B, Fernandez HH. Useful field of view as a reliable screening measure of driving performance in people with Parkinson's disease: results of a pilot study. Traffic Inj Prev 2009;10:593–8.
13. Silva MT, Laks J, Engelhardt E. Neuropsychological tests and driving in dementia: a review of the recent literature. Rev Assoc Med Bras 2009;55:484–8.
14. Duchek JM, Hunt L, Ball K, Buckles V, Morris JC. Attention and driving performance in Alzheimer's disease. J Gerontol B Psychol Sci Soc Sci 1998;53:P130–41.
15. Edwards JD, Vance DE, Wadley VG, Cissell GM, Roenker DL, Ball KK. Reliability and validity of useful field of view test scores as administered by personal computer. J Clin Exp Neuropsychol 2005;27:529–43.
16. Visual Awareness Inc. UFOV User's Guide. Birmingham, AL: Visual Awareness Inc.; 2002, revised 1/04.
17. National Highway Transportation Safety Administration (NHTSA). The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data. Washington, DC: National Highway Safety Traffic Administration, US Department of Transportation; 2006.
18. Hasher L, Zacks RT. Working memory, comprehension, and aging: a review and a new view. In: Bower GH, ed. The Psychology of Learning and Motivation. New York, NY: Academic Press; 1988:193–225.
19. Hasher L, Lustig C, Zacks RT. Inhibitory mechanisms and the control of attention. In: Conway A, Jarrold C, Kane M, Miyake A, Towse J, eds. Variation in Working Memory. New York, NY: Oxford University Press; 2007:227–49.
20. McGwin G, Brown DB. Characteristics of traffic crashes among young, middle-aged, and older drivers. Accid Anal Prev 1999;31:181–98.
21. Preusser DF, Williams AF, Ferguson SA, Ulmer RG, Weinstein HB. Fatal crash risk for older drivers at intersections. Accid Anal Prev 1998;30:151–9.
22. Cantin V, Lavalliere M, Simoneau M, Teasdale N. Mental workload when driving in a simulator: effects of age and driving complexity. Accid Anal Prev 2009;41:763–71.
23. Atchley P, Dressel J. Conversation limits the functional field of view. Hum Factors 2004;46:664–73.

24. Amado S, Ulupinar P. The effects of conversation on attention and peripheral detection: is talking with a passenger and talking on the cell phone different? Transport Res F Traffic Psychol Behav 2005;8: 383–95.
25. McEvoy SP, Stevenson MR, Woodward M. The contribution of passengers versus mobile phone use to motor vehicle crashes resulting in hospital attendance by the driver. Accid Anal Prev 2007;39: 1170–6.
26. Redelmeier DA, Tibshirani RJ. Association between cellular-telephone calls and motor vehicle collisions. N Engl J Med 1997;336: 453–8.
27. Horberry T, Anderson J, Regan MA, Triggs TJ, Brown J. Driver distraction: the effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance. Accid Anal Prev 2006;38:185–91.
28. Pashler H. Dual-task interference in simple tasks: data and theory. Psychol Bull 1994;116:220–44.
29. Wingfield A, Tun PA, McCoy SL. Hearing loss in older adulthood: what it is and how it interacts with cognitive performance. Curr Dir Psychol Sci 2005;14:144–8.
30. Avolio BJ, Kroeck KG, Panek PE. Individual differences in information-processing ability as a predictor of motor vehicle accidents. Hum Factors 1985;27:577–87.
31. Parasuraman R, Nestor PG. Attention and driving skills in aging and Alzheimer's disease. Hum Factors 1991;33:539–57.
32. Duchek JM, Hunt L, Ball K, Buckles V, Morris JC. The role of selective attention in driving and dementia of the Alzheimer type. Alzheimer Dis Assoc Disord 1997;11(Suppl 1):48–56.
33. Anstey KJ, Wood J. Chronological age and age-related cognitive deficits are associated with an increase in multiple types of driving errors in late life. Neuropsychology 2011;25:613–21.
34. Hickson L, Wood J, Chaparro A, Lacherez P, Marszalek R. Hearing impairment affects older people's ability to drive in the presence of distracters. J Am Geriatr Soc 2010;58:1097–103.
35. Chaparro A, Wood JM, Carberry T. Effects of age and auditory and visual dual tasks on closed-road driving performance. Optom Vis Sci 2005;82:747–54.
36. Wood J, Chaparro A, Hickson L. Interaction between visual status, driver age and distracters on daytime driving performance. Vision Res 2009;49:2225–31.
37. Edwards JD, Myers C, Ross LA, Roenker DL, Cissell GM, McLaughlin AM, Ball KK. The longitudinal impact of cognitive speed of processing training on driving mobility. Gerontologist 2009;49: 485–94.
38. Howell DC. Statistical Methods for Psychology, 4th ed. Belmont, CA: Duxbury Press; 1997.
39. Wood JM. Aging, driving and vision. Clin Exp Optom 2002;85: 214–20.
40. Szlyk JP, Seiple W, Viana M. Relative effects of age and compromised vision on driving performance. Hum Factors 1995;37:430–6.
41. Hakamies-Blomqvist L. Older drivers' accident risk: conceptual and methodological issues. Accid Anal Prev 1998;30:293–7.
42. Keskinen E, Ota H, Katila A. Older drivers fail in intersections: speed discrepancies between older and younger male drivers. Accid Anal Prev 1998;30:323–30.
43. Trick LM, Toxopeus R, Wilson D. The effects of visibility conditions, traffic density, and navigational challenge on speed compensation and driving performance in older adults. Accid Anal Prev 2010; 42:1661–71.
44. Baddeley A. Working memory. Science 1992;255:556–9.
45. Baddeley A. Working memory: looking back and looking forward. Nat Rev Neurosci 2003;4:829–39.
46. Pietras TA, Shi Q, Lee JD, Rizzo M. Traffic-entry behavior and crash risk for older drivers with impairment of selective attention. Percept Mot Skills 2006;102:632–44.
47. Chaparro A, Groff L, Tabor K, Sifrit K, Guguerty LJ. Maintaining situational awareness: the role of visual attention. In: Proceedings of the Human Factors and Ergonomics Society 43rd Annual Meeting, Houston, TX, 1999:1343–7.
48. Ball KK, Roenker DL, Wadley VG, Edwards JD, Roth DL, McGwin G, Jr., Raleigh R, Joyce JJ, Cissell GM, Dube T. Can high-risk older drivers be identified through performance-based measures in a Department of Motor Vehicles setting? J Am Geriatr Soc 2006;54: 77–84.
49. Grady CL, Craik FI. Changes in memory processing with age. Curr Opin Neurobiol 2000;10:224–31.
50. Raz N. Aging of the brain and its impact on cognitive performance: integration of structural and functional findings. In: Craik FIM, Salthouse TA, eds. Handbook of Aging and Cognition, 2nd ed. Mahwah, NJ: L. Erlbaum and Associates; 2000:1–90.
51. Clarke DD, Ward P, Bartle C, Truman W. Older drivers' road traffic crashes in the UK. Accid Anal Prev 2010;42:1018–24.

Joanne M. Wood
School of Optometry
Queensland University of Technology
Kelvin Grove
Brisbane, Queensland 4059
Australia
e-mail: j.wood@qut.edu.au