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RELATION OF USEFUL FIELD OF VIEW AND OTHER SCREENING TESTS TO ON-ROAD DRIVING PERFORMANCE[1]

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Summary.—The purpose of this study was to examine the value of a clinical driving assessment battery in predicting performance on an on-road driving test. 43 participants referred to the Bryn Mawr Rehab Adapted Driving Program for evaluation of driving ability underwent an evaluation consisting of a predriver screening and an on-road driving test. The predriver screening included a vision screening, a reaction time task, a split-attention task, the Hooper Visual Organization Test, verbal and symbolic sign recognition, and assessment of Useful Field of View. Logistic regression analyses were applied to identify which predriver screening variables could be used to predict outcome on the on-road driving test (pass/fail); UFOV® was that best single predictor. The addition of screening tests beyond UFOV® alone did not increase predictive validity. These findings suggest that UFOV® may serve as an indicator of the need for further driving assessment.

One of the most common concerns with older adults is their fitness to drive. Family members often become particularly concerned when a loved one has a medical problem, i.e., Alzheimer's disease, head injury, or stroke, affecting mental status or sensory function. Physicians, psychologists and occupational therapists are among the professionals who are asked to make a judgement regarding an individual's fitness to drive. While statistical data indicate that older adults have more automobile crashes per mile driven than any other adult age group, the vast majority are safe drivers (Evans, 1988, 1991). Also, driving is a very important activity in terms of maintaining mobility and independence for older adults. For example, an increase in depression and feelings of isolation has been observed in elderly individuals who no longer drive (Johnson, 1995; Marottoli, Mendes de Leon, Glass, Williams, Cooney, Berkman, & Tinetti, 1997). Therefore, it is important to develop a method of accurately assessing driving ability to identify high risk drivers without limiting the freedom of competent older drivers.

Driving ability has been assessed previously using self-report measures, state-provided driving records, driving simulators, and on-road driving tests (Ball & Owsley, 1991; Dobbs, 1997; Duchek, Hunt, Ball, Buckles, & Morris,

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1998; Fitten, Perryman, Wilkinson, Little, Burns, *et al.*, 1995; Galski, Ehle, & Bruno, 1990; Hunt, Morris, Edwards, & Wilson, 1993; Kapust & Weintraub, 1992; Nouri & Lincoln, 1993; Nouri, Tinson, & Lincoln, 1987; Odenheimer, Beaudet, Jette, Albert, Grande, & Minaker, 1994). Of these methods, road tests provide the most direct measure of driving performance. There are several disadvantages to this method, however. One drawback is that the administration of a driving test requires trained and experienced examiners to provide reliable results. Optimally, two individuals should be present during the evaluation, one to direct the driver and the other to assess performance. Also, there are safety and liability concerns when testing involves difficult driving conditions such as bad weather and heavy traffic (Ball & Owsley, 1991). In addition, there are many environments in which the administration of a road test is not feasible, i.e., no testing facilities in the local community, no insurance coverage, inability to privately pay for assessment. Therefore, it would be helpful to find such predictive tests for use in physicians' or psychologists' offices or the Department of Motor Vehicles to identify drivers who may need further assessment to determine fitness to drive. Dobbs (1997) suggested that a screening battery identifying both the most competent and the most dangerous drivers would be quite useful.

Several studies have examined the relationship between neurocognitive functioning and road test performance (Duchek, *et al.*, 1998; Fitten, *et al.*, 1995; Galski, *et al.*, 1990; Galski, Ehle, & Williams, 1997; Hunt, *et al.*, 1993; Kapust & Weintraub, 1992; Nouri & Lincoln, 1993; Nouri, *et al.*, 1987; Odenheimer, *et al.*, 1994). Most studies included a large battery of both neurocognitive and vision tests, ranging from 5 to 22 tests administered. All studies identified significant correlations between a subset of neurocognitive tests and road test performance (pass/fail). Although most studies merely examined the correlations between neurocognitive functioning and driving performance (Galski, *et al.*, 1990; Hunt, *et al.*, 1993; Kapust & Weintraub, 1992; Odenheimer, *et al.*, 1994), several studies did attempt to identify the best predictors of driving performance using regression or discriminant function techniques (Duchek, *et al.*, 1998; Fitten, *et al.*, 1995; Nouri & Lincoln, 1993). Nouri, *et al.* (1987), using discriminant function analysis, identified Dot Cancellation, Rey Figure, What Else Is In the Square, Pursuit Rotor, Token Test, Vision Testing, Recognition Memory, Cube Copying, and Hazard Recognition as most appropriate to include in a cognitive test battery. Duchek, *et al.* (1998) used stepwise regressions to identify the Boston Naming Test and several visual attention variables as significant predictors of on-road driving performance. Finally, Fitten, *et al.* (1995) identified the Folstein Mini-Mental State Examination, the Sternberg short-term memory test, and a visual tracking measure as significant predictors of driving performance using stepwise multiple regression. The findings of the latter two studies suggested that it may be possible to identify a relatively small number of tests as the most significant predictors of driving performance.

Owsley, Ball, Sloane, Roenker, and Bruni (1991) developed a theoretical model for predicting crash frequency in elderly drivers on the basis of visual and cognitive skills. Based on a relatively small sample of older adults (aged 57 to 83 years), this model illustrated that more cognitively oriented measures such as visual attention and mental status were the only variables that significantly predicted crash frequency. This model was subsequently tested on a larger sample of older adults using a LISREL structural modeling approach. This approach enables one to evaluate independent variables in terms of whether they directly influence the dependent variable or whether they operate indirectly through other variables. This model postulates that eye health, central vision, and peripheral vision have only indirect effects on crash frequency, but direct effects on visual attention measures such as the Useful Field of View. It further asserts that mental status has a direct effect on crash frequency as well as an indirect effect on crash frequency mediated through Useful Field of View (Ball, Owsley, Sloane, Roenker, & Bruni, 1993). The overall fit of this model to the test data of a sample of 294 older adults was excellent.

The purpose of the current study was to examine a battery of tests already in use in a driving clinic to identify the measures with the most predictive value in assessing outcome on an on-road test. With the exception of Useful Field of View, the measures used in this study were those typically used in the Bryn Mawr Rehab Adapted Driving Program. Useful Field of View was added to the battery because it has importance as an empirically derived predictor of crash frequency in older adults and is significantly correlated with on-road driving performance (Ball, *et al.*, 1993; Duchek, *et al.*, 1998; Roenker, Cissell, Ball, & Niva, 2000).

Useful Field of View is the spatial area within which an individual can detect visual stimuli in a variety of situations (Roenker, *et al.*, 2000). Useful Field of View, assessed using the UFOV® Visual Attention Analyzer (Visual Resources, Inc., Bowling Green, Kentucky), has three subtests, measuring speed of visual processing, ability to divide attention, and selective attention abilities. In the first subtest, the participant must identify a target, i.e., a silhouette of a car or a truck, of varying duration which is presented in a fixation box. In the second subtest, the participant must localize a simultaneously presented peripheral target (a silhouette of a car) in addition to the identification of the central target. The third subtest is the same as the second with the exception that the peripheral targets are embedded in distractors (triangles). An individual's Useful Field of View reduction can range from 0% to 90% in individuals with normal vision. Generally, a person with a

UFOV® reduction of 40% or greater is considered to be a high risk driver (Ball, *et al.*, 1993).

The Useful Field of View measure was developed to assess age-related limitations in visual search within the framework of a two-process model of attention. Earlier work identified age differences in both attentive and pre-attentive processing in visual search (Ball, *et al.*, 1993). One of the major challenges in aging research has been to identify age-related performance changes, examine the reasons for these age-related changes, and in the case of driving performance, understand how these age-related changes relate to everyday performance. Deficits in the Useful Field of View, which may occur due to age-related slowing of information processing, particularly under more challenging driving situations such as left-hand turns against traffic or performance at intersections, appear to be theoretically as well as empirically related to crash risk.

Method

Participants

The present participants were referred for evaluation to the Bryn Mawr Rehab Adapted Driving Program. Of 98 potential participants (80 men, 18 women; average age = 73 yr., range = 61–91 years; 97 Euro-American), 43 participants who completed the entire neuropsychological battery as well as the on-road driving test were included in the final sample. The remaining 55 patients had incomplete data for a variety of reasons. For example, a number of patients were not administered the full battery of neuropsychological tests used in this study and therefore are excluded in some analyses. Other patients were not administered the on-road test due to failure to pass the parking lot evaluation, need for adapted equipment training, or absence of a valid driver's license. However, eight participants who failed the parking-lot test were still included in the final sample, given that they would be assumed to have failed the road test also. Finally, 16 individuals were administered the road test but could not be scored as a clear pass or fail on the initial on-road assessment and were listed with questionable outcome.

Participants were patients referred by physicians from various disciplines of neurology, family practice, physical medicine and rehabilitation at Bryn Mawr Rehab or in the surrounding community. Each patient had a medical diagnosis, with the most common diagnosis being cerebrovascular accident (27 = right CVA, 19 = left CVA, 9 = other CVA). Other diagnoses included Parkinson's disease ($n=5$), hypertension ($n=1$), memory problems ($n=2$), traumatic brain injury ($n=5$), subarachnoid hemorrhage ($n=4$), hydrocephalus ($n=1$), seizures ($n=1$), right hip fracture ($n=1$), organic brain syndrome ($n=2$), subdural hematoma ($n=2$), peripheral neuropathy ($n=4$), transient ischemic attacks ($n=3$), cognitive changes ($n=1$), alcohol abuse ($n=2$), depression ($n=1$), spinal stenosis ($n=1$), chronic vertigo ($n=1$), Padget's disease ($n=1$), decreased reflexes ($n=1$), congestive heart failure ($n=1$), choreosthetosis ($n=1$), right above-the-knee amputation ($n=1$), and gall bladder series ($n=1$). The Institutional Review Board of the Lankenau Medical Research Center approved the research protocol and the consent form regarding the protection of human subjects.

Measures and Procedure

Upon referral to the Bryn Mawr Rehab Adapted Driving Program, patients were given a standard-practice battery of tests as part of a predriver screening. This battery included a visual screening which examined visual acuity using the Snellen eye chart, double simultaneous stimulation, visual tracking, saccades, and depth perception. With the exception of visual acuity, ratings of 1 = no deficit, 2 = mild deficit, or 3 = significant deficit, were given for each part of the visual screening. Other tests administered included UFOV®, a brake reaction time task, a split-attention task, the Hooper Visual Organization Test, and both verbal and symbolic traffic sign recognition tests. With the exception of UFOV®, this battery was clinically selected by experienced occupational therapists and was based upon the face valid association of each measure with driving performance.

Reaction time.—For the reaction time task, the AAA Reaction Time Tester was administered. Patients viewed a box with a green and a red light. When the red light went on they were to remove the foot from the gas pedal and depress the brake pedal as fast as possible. The average reaction time over 10 trials was used for analysis.

Split attention.—For the split-attention test, patients were given a peg board and asked to copy a pattern on the board using the pegs. Both hands could be used. The secondary task required the patient to put a green peg in a box every 15 sec. The measures used for this test were the number of green pegs missed, i.e., not put in the box, and the time (in seconds) required to complete the task.

Hooper Visual Organization Test.—The Hooper Visual Organization Test was developed to examine visual-perceptual functioning in patients with possible organic brain pathology (Hooper, 1983; York & Cermak, 1995). Administration consisted of showing patients 30 line drawings in which common objects, e.g., scissors, are cut into pieces and rearranged. The task is to identify the object correctly. Thirty was the maximum score possible on this test.

Verbal and symbolic sign recognition.—Participants were shown traffic signs and asked to identify them. Examples of verbal signs include "Road construction 1500 ft.," "Do Not Enter," "12′6″-clearance." Examples of symbolic signs include symbols representing no U-turn, no right turn, and slippery when wet. Participants could achieve a maximum score of 10 for each the of verbal and the symbolic sign tests.

UFOV®.—The size of the Useful Field of View was assessed using the microprocessor-based UFOV® Visual Attention Analyzer (Visual Resources, Inc., Bowling Green, Kentucky). This test has three subtests which measure speed of visual processing, ability to divide attention, and selective attention abilities, respectively. Each subtest score can range from 0 to 30 with 0 being a perfect score. The scores of the three subtests are summed to yield a composite score between 0 and 90, representing the total percentage of reduction of the Useful Field of View. In the first subtest, the participant was required to identify a target (the silhouette of a car or a truck) presented in a fixation box. The second subtest required the identification of the central target and the localization of a simultaneously presented peripheral target (a silhouette of a car). The peripheral target appeared at each of 24 different peripheral locations along eight radial spokes (four cardinal and four oblique) and three eccentricities (10, 20, or 30). To measure speed of visual processing, the duration of the display was varied. The third subtest was identical to the second except that the peripheral target was embedded in distractors (triangles).

On-road Driving Evaluation

After completion of the predriver screening, participants for whom there were no significant safety concerns and who had a valid driver's license were taken for an on-road driving evaluation. The road test involved a 10- to 15-min. warm-up in the parking lot to allow participants time to familiarize themselves with the car and its features. The road test was 13 miles long and involved driving on secondary roads, a suburban highway, a shopping center parking lot, and in downtown traffic. In addition to the driver, a driving instructor sat in the front seat to direct the patient along the course and an evaluator sat in the backseat to rate the driver's performance. Both the driving instructor and the evaluator were Certified Driver Rehabilitation Specialists.

Participants were rated as pass, fail, or questionable based on their performance on the road test. Participants who exhibited no difficulty and made no critical errors on the road test were rated as passing. A critical error that would lead to failure on the on-road test typically included running a stop sign or stoplight, inattention to critical stimuli, impaired lane position or gap judgment, significant judgment errors, or the need to use the training brake to avoid harm. Participants who did not make any critical mistakes but made more than two minor errors were rated as questionable. These individuals were given a chance to retake the road test at a later date. As there was not a clear initial outcome for these participants, they were not included in the current analyses and are discussed separately.

Results

Descriptive data for the visual screening variables and cognitive instruments are presented in Tables 1 and 2, respectively. Individual logistic regression analyses were conducted to examine the ability of each measure to predict performance on the driving test. The raw ratings (1, 2, or 3) were used in the analyses for the visual screening variables in Table 1, whereas the scores from continuous measures listed in Table 2 were first transformed into z-scores prior to analysis. This allowed comparison of odds ratios since each reflected the increase in odds associated with an increase of one standard deviation on the predictor. Odds ratios were tested for statistical significance using the likelihood ratio test. As reflected in Tables 1 and 2, visual tracking, visual acuity, reaction time, pegs missed, pegs time, Hooper Visual Organization Test, and UFOV® were all significantly related to outcome on

TABLE 1

Logistic Regression Analyses Comparing Visual Screening Variables to On-road Performance ($N=43$)

Variable	No. Participants With			Odds Ratio	95% CI
	No Deficits	Mild Deficits	Significant Deficits		
Visual fields	40	3	0	3.00	−1.32–4.22
Double simultaneous stimulation†	40	3	0		
Visual tracking	32	11	0	5.87*	0.32–3.45
Saccades	38	5	0	6.86	−1.10–4.95
Depth perception	37	5	1	3.19	−0.33–3.14

Note.—CI = confidence interval. Only participants with complete data are represented. *Odds ratio significantly different from 1 ($p<.05$). †Due to lack of variability, logistic regression was not conducted for this measure.

TABLE 2

Logistic Regression Analyses Comparing Continuous Predriver Screening Variables to On Road Performance ($N=43$)

Variable	*M*	*SD*	Min.–Max.	Odds Ratio	95% CI
Visual acuity	0.14	0.10	0.00–0.40	2.28*	0.16–1.61
Reaction time	0.51	0.16	0.34–1.10	3.53*	0.34–2.54
Pegs missed	2.58	2.89	0.00–13.00	3.24*	0.37–2.22
Pegs time, sec.	277.77	86.31	120.00–488.00	2.62*	0.24–1.89
HVOT	22.21	3.02	14.00–27.00	0.34*	−2.01– −0.35
Symbolic signs	8.14	1.55	4.00–10.00	0.66	−1.10–0.20
Verbal signs†	9.95	0.21	9.00–10.00		
UFOV®	41.58	16.67	17.50–90.00	13.43*	1.29–4.50

Note.—CI = confidence interval. Only participants with complete data are represented. *Odds ratio significantly different from 1 ($p<.05$). †Due to lack of variability, logistic regression was not conducted for this measure.

the driving test when examined individually. The odds ratios indicated that UFOV® had the strongest relationship with the driving test results.

Next, a multiple logistic regression model was constructed that included all seven of the variables which were significant individual predictors. The overall model was significant [$\chi^2(7) = 31.357$, $p = .0001$]. Chi-squared difference tests were then conducted to determine whether this model fit significantly better than the models that included only one predictor at a time. These analyses showed that the prediction achieved with the seven-variable model was not significantly better than the prediction achieved by UFOV® alone [$\chi^2(6) = 7.69$, $p > .05$].

Table 3 presents the classification results for the UFOV® model and for the seven-variable model. The UFOV® model correctly classified the on-road driving performance of 86% of the study sample. Interestingly, only six patients (14%) were misclassified using UFOV® in isolation, whereas nine patients (21%) were misclassified using the fuller model.

TABLE 3
Classification Results For UFOV® Model Versus Seven-variable Model ($N = 43$)

Predicted Outcome	Actual Outcome	
	Fail	Pass
UFOV® Only		
Fail	14	2
Pass	4	23
Seven-variable Model		
Fail	14	5
Pass	4	20

Note.—Only participants with complete data are represented.

Table 4 displays the predicted probabilities of failing the on-road driving test for patients with specific UFOV® scores. The logistic regression model indicates that one's risk of failing the road test increases in a linear manner. In other words, higher UFOV® scores indicate a greater risk of failing the road test. For UFOV® scores of 70% and over, the probability of failing the road test is over 80%.

Participants with questionable road-test outcomes ($n = 16$) were not included in the previous analyses; however, observation of their performance on UFOV® indicates that most of these participants passed UFOV® ($n = 11$). In addition, after further evaluation and/or training, most of the 16 participants with initial questionable ratings passed the road test ($n = 10$).

Discussion

The assessment of driving competence has traditionally been made with a test of on-the-road driving performance. This test may occur at state drivers' licensing facilities or through certified driving evaluations, most typically administered by occupational therapists who assess sensory and cognitive function as well. Previous studies have concluded that cognitive function tests alone are not adequate to predict driving performance (Brooke, Questad, Patterson, & Valois, 1992) and that many drivers may have perceptual or cognitive deficits that do not appear to influence their performance. Clinical measures have more typically been used by driving evaluators to complement the on-road assessment (Jones, Giddens, & Croft, 1983), to help to explain driving recommendations to the driver, family, or referral source (Strano, 1997), and to gather important information about a driver which could help to explain any driving difficulties (Galski, Ehle, & Bruno, 1990).

TABLE 4
Predicted Probabilities of Failing On-road Test For Various UFOV® Scores ($N = 75$)

UFOV® Reduction Score	Predicted p
0	.08
10	.13
20	.21
30	.31
40	.44
50	.58
60	.71
70	.81
80	.88
90	.93

Note.—Seventy-five participants with both UFOV® scores and a clear pass/fail on the road test are included.

Over the past 10 years, however, there has been a dramatic increase in the number of studies conducted to evaluate the driving performance of older adults specifically. These studies have led to the development of new measures of driving competence, and it is important to evaluate them relative to the road test, as conducted in clinical practice, as well as relative to other traditionally used clinic measures. The development of better methods for identifying problem older drivers has become an important national issue as the population continues to age. Health care professionals are increasingly called upon by older adults and their family members to make recommendations regarding fitness to drive. Such questions are often legitimate since older adults on average are more likely to have an auto accident per mile driven than other adult age groups (Evans, 1988, 1991). However it is equally important not to discriminate against the majority of older drivers who are competent behind the wheel.

The results of this study are promising for health care professionals, as they suggest that new measures are being developed which are useful in assessment of older individuals' competence to drive. Out of a total of 12 clinical measures used in this study, seven independently distinguished between individuals who passed and failed the road test. However, the newly developed test of Useful Field of View was slightly more accurate in classifying passing and failing drivers than all seven clinical measures combined. One possibility for this finding is that the Useful Field of View test is a measure of visual processing, including divided and selective attention abilities. Thus, the use of tests which measure similar abilities, i.e., split attention and Hooper's test, provides redundant information. This is not to suggest that other tests do not provide useful information even if they are not the best predictors of outcome. For example, the reaction time test and visual field tests provide information on why an individual may be having driving difficulty, and that information could be used for intervention purposes.

The current results suggest that it may be possible to use the Useful Field of View as a brief and efficient screening test in a variety of settings to identify which drivers are at risk and should be referred for further on-road testing. Also, if such screenings were ever done on a broad scale, this measure could be a useful tool in identifying the drivers with an extremely low predicted probability of failing a road test who do not require further evaluation, and those individuals with an extremely high predicted probability of failing a road test who may elect not to go through further testing.

Although there is considerable debate as to whether a test such as UFOV® should be used to make decisions regarding driver competence, one important use is to identify individuals who could benefit from training to improve driving skills. Recent research has indicated that, with Useful Field of View training, older adults learned to expand the size of their attentional field, a skill which transferred to fewer dangerous maneuvers in an on-road driving evaluation (Roenker, *et al.*, 2000). Therefore, older persons who desire to continue to drive but fail on-road driving tests due to deficits in visual attention may be able to improve their skills with appropriate training. It will be important, however, to evaluate the driving improvement possible after Useful Field of View training of patients who have impairments due to a medical event such as a cerebrovascular accident.

There are several limitations to the current study. The first limitation is that only patients who had completed the full assessment battery were included in most of the analyses in this study. Due to clinical and time considerations, there were other patients who were evaluated at Bryn Mawr Rehab but did not complete all tests and thus their data were not included. This may have biased data as range of scores was restricted for some variables. An additional observation is that the majority of patients exhibited no deficits on the visual screening variables. The lack of variability in these measures limited their usefulness for predicting driving performance. This finding may be misleading given that those patients with poor vision did not advance to the on-road assessment or that many patients with poor vision are not even referred for assessment. Also, this finding does not suggest that vision is unimportant in driving, just that it is a necessary but not sufficient condition.

Likewise, the prescreening battery in the current study, with the exception of Useful Field of View, focused on face-valid attentional, perceptual, and spatial abilities but did not broadly assess cognitive impairment in areas encompassing frontal abilities such as executive function, planning, and judgment. It is likely that such deficits would negatively affect driving performance and, indeed, such deficits may have played a role in the failure of some participants to pass the parking-lot evaluation of the present study. These failures, in turn, excluded the participants from subsequent on-road driving assessment. The authors acknowledge that cognitive prerequisites to safe driving following an insult such as CVA should be heavily weighed in the decision to perform an on-road evaluation. Furthermore, cognitive function should be weighed along with visual function and performance outcome data as joint indices of readiness to return to driving.

A final note with respect to cognitive screening in the current study is that UFOV® reductions may be influenced by a variety of cognitive and mental status impairments as well as visual impairments. Thus, UFOV® performance in the present study may to some extent represent the influence of a broader array of cognitive variables that were not directly measured.

Another limitation is that there was no standardized rating scale used for rating on-road driving performance. Instead, patients were rated as passing if they did not exhibit any serious errors in driving, e.g., running a stop sign or stoplight. This is not likely to produce as reliable a measure as road-tests with standardized rating scales and multiple raters as have been used in previous research protocols (Duchek, *et al.*, 1998; Fitten, *et al.*, 1995; Roenker, *et al.*, 1998). The method used in this study, however, is likely more typical of actual clinical practice than the more detailed and standardized research protocols (Galski, *et al.*, 1997).

Research is required to develop effective methods of expanding Useful Field of View with the goal of keeping older individuals as mobile as possible. Given that older adults comprise 28% of all drivers in the year 2000 (Malfetti, 1985; National Safety Council, 1989), the identification of at-risk drivers and subsequent provision of training for the improvement of driving skills is an important objective.

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