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Predicting Road Test Performance in Drivers with Dementia

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Abstract

Objectives—To develop a cognitive and functional screening battery for the on-road performance of older drivers with dementia.

Design—A prospective observational study.

Setting—On-road driving evaluation clinic at an academic rehabilitation center

Participants—Ninety-nine older people with dementia (63% male, mean age = 74.2 years, SD= 9), referred by community physicians to an Occupational Therapy driving clinic.

Measurements—The outcome variable was pass/fail on the modified Washington University Road Test. Predictor measures were tests of visual, motor and cognitive functioning, selected for their empirical or conceptual relationship to the complex task of driving safely.

Results—Sixty-five (65%) of participants failed the on-road driving test. The best predictive model, with an overall accuracy of up to 85% when participants were blinded, included AD-8 score, the Clock Drawing Test score, and the time to complete either the Snellgrove Maze Test (SMT) or Trail Making Test A. Visual and motor functioning were not associated with road driving test failure.

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Author Contributions:

David Carr: Designing the study, methodology, interpretation of data, preparation of manuscript.

Peggy Barco: Study design, collection and interpretation of data, preparation of manuscript.

Mike Wallendorf: Study design, interpretation of data, statistical analysis, and preparation of manuscript.

Carol Snellgrove: Provision of the Snellgrove Maze Task®, interpretation of data, preparation of manuscript.

Brian Ott: data analysis, interpretation of data, preparation of manuscript

Sponsor's Role: The sponsor had no role in the design, methods, subject recruitment, data collections, analysis and preparation of paper.

Conclusion—A screening battery that could be performed in less than 10 minutes predicted with good accuracy a failure rating on the on-road driving test in this sample of older drivers with dementia. A “probability of failure” calculator is provided from a logistic regression model that may be useful for clinicians in their decision to refer impaired older adults for further testing. More studies are needed in larger community based samples, along with discussions with patients, families and clinicians, in regards to acceptable levels of test uncertainty.

Keywords

on-road driving safety; dementia; older drivers

INTRODUCTION

Studies of drivers with dementia have shown elevated crash rates compared to healthy controls[1], impaired performance on road tests[2], and difficulty in traffic skills on driving simulators [3]. Consequently, clinicians are often called upon by their colleagues, families[4] and at times the Department of Motor Vehicles[5] to assist with the difficult decision of whether a older adult with dementia is fit to drive.

Discrete cognitive domains are essential for the safe operation of an automobile. These include well learned visuospatial and praxis (visuoconstructional) skills which are supervised by the executive system of the brain and require significant attentional capacity. These cognitive domains have been shown to be associated with impaired driving in older people [6]. The majority of studies that have attempted to create cognitive test models for road test performance in older adults with dementia typically approach an 80% correct classification rate when using multiple tests [7].

In the current study, we aimed to improve on previous predictive models of driving performance by using a combination of cognitive and functional assessment tools that could be easily administered by clinicians and adopted at low cost in any setting. The major thrust of this specific set of analyses was not to prescribe the final decision on who is fit-to-drive, but to develop a risk model of predicting hazardous driving behaviors, which could then be used to determine who is most appropriate for referral for performance-based road testing.

METHODS

This study was approved by the Human Studies Committee at Washington University and HealthSouth Research Committee Corporate Office, who is the managing partner with Barnes-Jewish Hospital at The Rehabilitation Institute of St. Louis (TRISL).

Participants/Recruitment

Participants were referred to our driving evaluation between December of 2007 and was completed in September of 2009. Recruitment occurred via lectures to clinicians on the Washington University campus, hospital newsletters, physician letters, emails, visits to the local chapter of the Alzheimer’s Association, and word-of-mouth. Driving clinic brochures were given to offices at subspecialty clinics and our rehabilitation center.

Inclusion Criteria—Inclusion criteria were as follows: a current driver with an active license; at least 10 years driving experience; at least 25 years of age; an informant (e.g. typically a spouse or adult child); a physician referral with a primary diagnosis of dementia; participation in any portion of the on-road test even if the evaluation was terminated prematurely; the ability to communicate in English; and an AD-8 score ≥ 2 (a brief questionnaire to detect the presence of dementia) [8] provided by the informant during

telephone screening. The cut-off level of 2 or greater (higher scores indicating higher levels of cognitive and functional impairment) predicts the presence of dementia with a high degree of sensitivity and specificity [8].

Exclusion Criteria—Exclusion criteria were as follows; refusal to participate by either the participant and/or informant; active depression; unstable illness (e.g. recent seizure); severe musculoskeletal deformity (e.g. amputation); sensory or communication impairments that would interfere with psychometric testing or instructions during road testing (e.g. severe vision, hearing and/or language deficits); medications causing sedation; judged to be too cognitively impaired or fatigued to follow road test instructions by the OT administering off-road tests; and any previous driving evaluations within the last 12 months.

Telephone Screening—Three hundred and seventeen 20-minute telephone screens were performed one to two months prior to the driving clinic evaluation with an informant, to assure inclusion and exclusion criteria were met. Two hundred and eighteen were excluded for a variety of reasons. The majority of the exclusions were due to refusal to participate, the presence of medical conditions that met our exclusion criteria (defined below), or expired licenses. A total sample of 99 participants were recruited, along with their informants. The study covered the cost of the road test evaluation as an incentive to participate in the evaluation process. It was made clear to the informant and the participant through this process and on the day of the clinic visit that the evaluation was at the request of the referring physician due to concerns about unsafe driving.

Data Collections and Measurements

Location—The DrivingConnections outpatient clinic of The Rehabilitation Institute of St. Louis (TRISL) is affiliated with the Washington University Medical Center and Barnes-Jewish Hospital. The Clinic is a collaboration between the Program of Occupational Therapy and the Division of Geriatrics and Nutritional Science at Washington University St. Louis, The Rehabilitation Institute of St. Louis (TRISL), and Independent Drivers, LLC. The Program of Occupational Therapy at Washington University and TRISL/HealthSouth provided occupational therapists and Independent Drivers, LLC provided the 4-door sedan with the dual set of brakes and the driving instructor.

Psychometric Test Administration and Training

Staff Qualifications/Training—The lead occupational therapist/driving rehabilitation specialist (OTR/DRS) was trained by a psychometrician from the Alzheimer's Disease Research Center in the standardized administration of the psychometric tests. The lead OTR/DRS trained 2 occupational therapists and one occupational therapist assistant (COTA) in performing driving assessments in a standardized manner for this current study. The OT's/COTA initially had direct observation of the administration of the measures by the lead therapist and then administered these measures with the lead therapist present until proficiency was established. The OT's that administered off-road tests never performed the role of the driving instructor on the road test, but were present and participated in the final discussion with the participant and informant after the driving evaluation was completed.

Off-Road Tests of Functional Abilities

Once the participant and proxy had read and signed informed consent and turned in their questionnaires, the OT in the driving clinic proceeded with tests of vision, cognition, and motor abilities. The off-road testing of the participant lasted approximately 90 minutes.

Vision—The participant was tested for both far and near visual acuity and visual fields with the Stereo Optical Optec 5500P [9]. Contrast sensitivity was tested by the Pelli-Robson contrast sensitivity chart[10].

Cognition—Tests administered included the Short Blessed Test [11](a brief mental status screen); the Clock Drawing Task [12] (test of executive function and visual spatial abilities) Trail Making Test A (test of attention, psychomotor speed, and visual scanning) and Trail Making B (test of alternating attention, psychomotor speed, executive function, and visual scanning)[13]; Digit Span Test Forwards and Backwards [14] (immediate and working memory respectively); two subtests from the Driving Health[®] Inventory (DHI) [15], which includes subtest 2 of UFOV[®] (“useful field of view”-a test of divided visual attention/visual memory and speed of processing [16], the Motor Free Visual Perceptual Test (test of visual closure)[30]; the Snellgrove Maze Task (SMT) [®] (attention, visuoconstructional ability, and executive functions of planning and foresight)[17]. The Short Blessed Test cut-off score for an abnormal screen is typically set at a score of 9 or higher (higher scores indicating more impairment), which corresponds to an Mini-Mental State Score (MMSE) score of 24 (lower scores indicating more impairment) (18). For all cognitive tests, higher scores indicated more impairment except for the Clock Drawing Task (using the Freund scoring method) and Digit Span Forward and Backwards.

Motor—The upper extremities and lower extremities were evaluated for range of motion and strength using standard physical examination techniques. Cervical range of motion measurements in degrees was obtained using standard goniometric techniques. Grip strength was assessed using the Jamar grip dynamometer for each hand averaging the sum of three trials (19). The Rapid Pace Walk [20] and the 9-Hole Peg test [21], a test of motor speed and agility, were also administered in our study, along with Brake Reaction Time (BRT) [22].

Outcome Measure

Design—The modified Washington University Road Test (mWURT) was used as the major outcome measure in this study and was reconstructed using common traffic situations and road maneuvers from the previous WURT [23]. The course has a many unprotected left hand turns along with complex merges and intersections in the later aspects of the route. The unprotected left hand turns were included, since older adults are over represented in crashes while performing this specific driving task [24]. Additionally, a small part of the course includes self navigation (i.e., being able to find way out of a parking lot independently and then a return to the correct road).

The mWURT consists of two components: the closed course and the open course. The closed course is started in a large parking lot. Driving in the parking lot allows the participant to become familiar with the car and the surroundings. If the participant is able to demonstrate proficiency with the basic operations of the automobile and follow instructions, they proceed to open course traffic. The course was graduated towards increasing difficulty, with more challenging tasks in the latter aspects of the route. The mWURT course was 12 miles long and took approximately 1 hour to complete per participant.

Rating—The participant drives a standard car with dual brakes while an OTR/DRS (instructor) sits in the front seat monitoring safety of the vehicle and evaluates driving performance. At the end of the drive, an overall score or qualitative rating of traffic performance is provided by the instructor, similar to the previous WURT; pass, marginal, and fail. A “fail” rating on the modified Washington University Road Test (mWURT) was the outcome measure of this study.

In 41 cases another evaluator was present in the back seat of the car, providing a measure of inter-reliability with the front seat driving instructor. The inter-rater reliability of pass combined with marginal scores was compared to fail ratings for both examiners. The kappa statistic for this comparison was good ($\kappa = 0.84$).

Blinding—The OT's who administered cognitive tests were separate from the instructor who provided the rating of pass, marginal or fail. However, the off-road OT's were allowed to provide the instructor key safety concerns (e.g. presence of visual field cuts such as hemianopsia, slow initiation or processing speed based on psychometric test performance, global results of tests and/or language impairments) that they believed would be critical for instructor to know for individual and public safety reasons. The OT's that performed the off-road tests were required to document when this type of information was given, along with the type of information that was communicated to the instructor. In 43 cases, our driving instructor was completely blind to any information from the off-road OT's. In 56 cases, the off-road OT's that administered our psychometric tests were compelled to "break the blind," and provide the driving instructor in the front seat with information on off-road test performance. This had potential to bias our road test results. Therefore, we also tested the final model with the total sample and a subsample where the instructor was completely blinded to off-road test performance. Statistical analysis was performed using SAS [25].

RESULTS

Table 1 reveals the demographic information, driving behaviors and non-cognitive measures of participants. Demographic and driving behavior variables were not associated with road test failure. Of the visual and motor variables, the measure of contrast sensitivity, left-handed 9-hole peg test and brake reaction time were significantly related to road test failure ($p=0.05$, 0.018 , and 0.013 , respectively). The presence of visual field "cuts" was based on whether our participants missed any of the 8 possible stimuli (4 for each left and right field of view) that were presented during testing on the Optec instrument.

Table 2 lists the cognitive /perceptual psychometric test results. We found significant correlations for the majority of these scores with a fail rating on our road test, when compared to those with marginal and pass ratings combined. Some tests have smaller sample sizes due to a variety of factors; the test may have been adopted later after the study was initiated (e.g. DHI, UFOV and MFVPT), the test may have been too difficult, the participant may have been fatigued or refused testing, computer hardware problems, or rarely missing data. It should be noted that 40% of our sample was unable to perform Trail Making Test B, and in this instance they were given a ceiling score of 301 secs.

Using a stepwise multiple logistic regression approach, the screens that performed best in predicting failure on our road test were the AD-8 total score, the Clock Drawing Task (CDT) and either Trail Making Test A time or the SMT time (model likelihood ratio test $p<0.001$, See Figure 1). In simple logistic regressions, these individual variables had AUC's between 0.75 and 0.77. The Pearson correlation between SMT and Trail Making Test A was relatively high (.6), indicating they are likely tapping into similar cognitive domains.

The fail rate was not statistically significant between un- blinded group (fail rate 69%, $N=56$) and blinded group (fail rate 60%, $N=43$). The logistic regression model for the combination of tests that included Trail Making Test A, CDT, and total AD-8 score had an $AUC=0.91$ for the non-blinded sample and 0.84 for the blinded sample. The model that included the SMT in lieu of Trail Making Test A had an $AUC=0.93$ for non-blinded sample and 0.85 for the blinded sample. None of the non-cognitive variables added to our predictive models.

Using the model with the Snellgrove Maze Test, a cut-off point set at $\geq 73\%$ probability of failure or higher for a combination of the three tests would identify 41 of the 65 demented drivers that failed our road test and would incorrectly identify only 2 participants from our sample that were given a pass or marginal rating (44% of the total sample, sensitivity of 67% and specificity of 94%). Conversely, a cut point of $\leq 23\%$ probability of failure would identify 8 drivers who were fit to drive with only identifying 1 driver who failed our road test (representing an additional 9% of the sample, with a sensitivity of 98% and specificity of 24%).

A “probability of road test failure” equation is derived from the logistic regression equation;

$$Prob(Fail) = \frac{e^{X\beta}}{1 + e^{X\beta}}$$

where $X\beta = -1.5609 + (0.0399 * SMT) + (-0.4460 * CDTF) + (0.5622 * AD8TOT)$ and $e = 2.718282$.

Copies of a sample calculator that include both models embedded in an excel file that requires only entry of the raw data scores of each of the three tests, is available upon request.

DISCUSSION

Almost two-thirds of the drivers with dementia in this study sample failed our road test. This is higher than previously reported studies [26]. However, such studies recruited samples in a research setting where one might anticipate a higher level of driving skills due to volunteer bias. This study examined patients that were deemed “at-risk” due to concerns raised by health professionals or families, including 20% who had been instructed to stop driving until further evaluation.

Recent reviews have found that similar tests of visuoconstructional skill, psychomotor speed, and attention have often assisted with prediction models [6], [7], providing convergent validation for our approach. The use of multiple tests to predict failure on road tests appears superior to attempting to find one ‘best’ test and is consistent with many other studies in the literature. However, if tests are too difficult they may be unacceptable to our patients and also limit their ability to discriminate safe from unsafe drivers. The AD-8, Trail Making Test A or SMT, and the Clock Drawing Test can, together, be performed in less than 10 minutes in any clinician’s office, to calculate the “risk” of on-road test failure.

The Snellgrove Maze Task (SMT) ® has some benefits over Trail Making Test A. It is not language based, therefore ensuring that more culture-fair classifications will result. It is also not covered by any Psychological Practices Acts, so may be administered by all health clinicians, and not restricted to use by psychologists. Other studies have reported utility for both hand-drawn[27] and computerized mazes[28] for this purpose; therefore, further development of such tests is indicated.

A probability of road test failure calculator can be created by using the logistic regression equation and the appropriate coefficients, intercept and specific scores on three tests. The probability statement of a “fail” rating on a road test could serve as a discussion point for clinicians and their clients. For instance, if the scores of the three tests indicated a patient with a high probability of failure, this may be a situation where the clinician counsels the participant and family that it is time to consider driving cessation and not spend resources (e.g. time, finances) on a formal driving evaluation. Alternatively, if the scores on the three tests indicated a low probability of failure, one might elect to continue to monitor the patient

over time. More discussion is needed on the placement of cut-offs, the level of test uncertainty that is acceptable to clients, families and professionals, and the percentage of the sample that is carefully characterized in order to consider adopting these types of tests.

There are several limitations to this study. Our road tests and predictive tests have not yet been validated with retrospective or prospective crash data. In addition, the majority of drivers were not familiar with the course, making it difficult to know if their performance was reflective of usual driving abilities on their more familiar routes. Some of the drivers were instructed by their physician to cease driving prior to the formal on-road evaluation. We were unable to determine the compliance with these recommendations, but acknowledge there is a potential that limited driving activity prior to the evaluation could have had an impact on road test results. Other domains were not studied that could have had the potential to improve prediction in our models (e.g. test anxiety, fatigue, personality traits, lifelong driving habits).

In summary, a combination of screening tests of impaired activities of daily living or function (the AD-8), visuoconstructional and executive function skills, particularly those pertaining to planning and foresight (Clock Drawing Test, SMT), and visual search and attention (Trail Making Test A, SMT), were able to classify with a high degree of accuracy, cognitively impaired drivers' performance on a standardized road test. All of the tests or screens in these models are easy to administer and score, as well as brief. Therefore, they may be attractive to community clinicians for use in office practice, although appropriate training of staff, time to administer the screens, and reimbursement issues may limit their utility and adoption.

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Conflict of Interest

David B. Carr is supported by NIH, Pfizer, MoDOT-Division of Highway Safety

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We also want to acknowledge support for our driving program from The Rehabilitation Institute of St. Louis and Stephen Ice at Independent Drivers, LLC for providing his expertise and assessments for all the road tests performed in this study. The *Eight-item Informant Interview to Differentiate Aging and Dementia (AD-8)* is a copyrighted instrument of the Alzheimer's Disease Research Center, Washington University, St. Louis, Missouri (2005). The AD8 is not a substitute for clinical judgment. For information about the Snellgrove Maze Task® please contact the author, Dr Carol Snellgrove, at carol.snellgrove@health.sa.gov.au".

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Figure 1.
ROC CURVE for the test combination of Snellgrove Maze Task®, AD-8, Clock Drawing Task.

Table 1

Demographics and non-Cognitive Measures Based on Road Test Outcome

Characteristic	Total Sample (N=99) Avg±SD/Range	Pass Road Test (N=34) (35%)	Fail Road Test (N=65) (65%)	P-Value
Age (years)	74.2±9.0 (52–90)	73.4±9.3 (52–84)	74.7±8.9 (52–90)	0.49
Gender (% M)	63%	68%	61%	0.56
Education (years)	14.8±3.3 (8–20)	15.1±2.8 (8–20)	14.6±3.5 (8–20)	0.50
Race (% AA)	12%	10%	13%	0.71
Driving Experience (years)	57.2±9.3 (36–76)	56.5±9.7 (36–72)	57.5±9.1 (36–76)	0.62
Days per Week Participant Drives	5.1±2.2 (0–7)	5.6±1.9 (2–7)	4.9±2.2 (0–7)	0.29
Miles per Day	16.6±11.8 (0–62)	19.9±13.5 (2–63)	15.0±10.6 (0–50)	0.09
1 or More Crash Previous Year	19 (20%)	6 (16.7%)	13 (21.3%)	0.70
Visual Acuity Far OU	27.7±9.4 (20–70)	26.8±8.4 (20–40)	28.2±10.0 (20–70)	0.49
Contrast Sensitivity (logMar)	1.6±.16 (1.2–2.0)	1.7±.14 (1.4–2.0)	1.6±.16 (1.2–2.0)	0.049
Presence of Any Abnormal Score on Visual Field Test? (Yes)	37.1%	26.5%	42.9%	0.11
Cervical Range of Motion Left (degrees)	57.7±8.6 (30–76)	57.6±7.7 (38–76)	58.2±8.8 (30–75)	0.53
Cervical Range of Motion Right (degrees)	57.8±7.9 (30–76)	57.7±7.5 (38–76)	57.7±8.8 (30–72)	0.99
Rapid Pace Walk (secs)	8.0±2.2 (4.5–15.4)	7.5±2.4 (4.7–15.0)	8.3±2.0 (4.5–15.4)	0.12
9 Hole Peg Right (secs)	28.5±7.2 (18.3–57.9)	26.7±6.0 (18.4–42.0)	29.4±7.6 (18.3–57.9)	0.08
9 Hole Peg Left (secs)	29.6±13.4 (18.2–143)	26.2±4.8 (18.2–35.8)	31.4±16.0 (19–143)	0.018
Grip Strength Right (lbs)	61.2±20.5 (20–115)	64.1±21.1 (22–115)	60.0±20.2 (20–107)	0.29
Grip Strength Left (lbs)	57.7±19.8 (19–133)	60.0±16.6 (20–96)	56.4±21.3 (19–133)	0.39
<u>Brake Reaction</u> (Secs)	.85±.64 (.43–4.8)	.62±.24 (.43–1.9)	.98±.74 (.47–4.75)	0.013

Table 2

Selected Psychometric Tests Based on Road Test Outcome

Measure	Total Sample (N=99) Avg±SD/Range	Pass Road Test (N=35) (35%)	Fail Road Test (N=65) (65%)	P-Value
<u>Short Blessed Test (SBT)</u> (N=99)	8.9±6.9 (0–28)	5.8±5.3 (0–24)	10.5±7.2 (0–28)	0.003
<u>Maze Test</u> (secs) (N=96)	49.5±35.1	35.2±12.3	62.5±43.9	0.001
<u>Clock Drawing Test-Freund</u> (0–7) (N=98)	4.9±2.3 (0–7)	6.2±1.2 (2–7)	4.2±2.5 (0–7)	0.0004
<u>Trail Making Test A</u> (secs) (N=98)	68.1±39.5 (20–88.5)	45.8±17.2 (19.5–89.0)	79.9±42.8 (19.6–151)	0.0007
<u>Trail Making Test B</u> (secs) (N=85)	196.9±86.0 (42–301)	151.8±75.7 (42–301)	226.9±79.6 (61–301)	0.0002
AD-8 Total (N=99)	5.3±1.7 (2–8)	4.3±1.5 (2–7)	5.8±1.6 (3–8)	<.0001
# Digits Forward (N=99)	7.8±2.2 (2–12)	8.2±2.2 (3–11)	7.6±2.3 (2–12)	0.23
# Digits Backward (N=99)	4.8±2.1 (0–10)	5.6±1.9 (2–10)	4.4±2.0 (0–10)	0.0094
Motor Free Visual Perception Test (# incorrect) (N=74)	3.9±2.8	3.1±2.7	4.5±2.8	0.16
Useful Field of View® (msec) (N=56)	276.4±148.1	216.8±129.0	342.9±136.5	0.012