Predicting On-Road Driving Performance and Safety in Cognitively Impaired Older Adults

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OBJECTIVES: To evaluate the ability to predict on-road driving in cognitively impaired older drivers.

DESIGN: Cross-sectional observational study.

SETTING: Laboratory tests and on-road assessment.

PARTICIPANTS: Drivers with cognitive impairment (Mini-Mental State Examination score < 26, N = 43, mean age 74).

MEASUREMENTS: The Roadwise Review, a hazard perception test (HPT), several vision tests, and a standardized 18-km driving assessment.

RESULTS: The best prediction of passing or failing the on-road test was a combination of the HPT, leg strength, visual acuity, visual search and working memory, and number of medications taken (Nagelkerke coefficient of determination = 0.40). The sensitivity of the model was 71%, and the specificity was 75%.

CONCLUSION: Further research is required to determine how these tests may be used or combined with other data (e.g., medical history) to assess fitness to drive of cognitively impaired older drivers. **J Am Geriatr Soc 63:2365–2369, 2015.**

Key words: cognitive impairment; hazard perception; roadwise review; driving

Older drivers have the highest rate of collisions per distance driven, even when self-imposed driving restrictions are taken into account.[1] This risk is even greater in drivers who have cognitive impairment such as Alzheimer's disease, who are 2.5 to 4.7 times as likely as healthy, age-matched controls to be involved in collisions.[2] The relationship between cognitive impairment and driving risk generalizes across outcome measures, including simulated car crashes at intersections[3] and in driving simulators in general.[4] Drivers with mild dementia are also more likely than cognitively normal adults to be deemed unsafe in an on-road driving test.[5,6] Safety considerations alone motivate the goal of predicting who is safe to drive and who poses undue risk in this vulnerable population.

Driving is a complex task, and multiple abilities, including strength, vision, attention, memory, and executive control are related to performance.[7] Several tools measuring these abilities have been used to assess fitness to drive in older adults. These include the Driving Health Inventory (DHI) (marketed as the Roadwise Review)[8] and hazard perception tests (HPTs).[9–11] The DHI comprises many of the tests previously shown to predict on-road safety, including several tests of vision, lower-body strength, attention (useful field of view (UFOV)), visual search, and memory (Trails Test). Its predictive utility in assessing driver fitness in healthy older adults has been inconsistent.[12–14]

Failure to respond appropriately to hazards increases driver risk.[15,16] In recognition of this, more recent driver-screening instruments for licensure and evaluation are HPTs,[17] which are designed to measure one's ability to detect and respond to hazards in the driving environment using reaction time as the primary dependent measure. Older drivers are slower than younger drivers at hazard perception,[12] and HPTs have been associated with crash involvement in various adult samples,[18,19] including older adults.[12] It was recently found an HPT was a significant predictor of several driving safety measures.[14] That brief HPT, a measure of walking speed from the Roadwise Review and color vision, yielded a sensitivity of 82% and a specificity of 69% in pass–fail outcomes on the driving evaluation.

Uncertainty regarding how to assess driving performance complicates the prediction of driving safety. Many jurisdictions use a system whereby points are assigned for unsafe driving behaviors (e.g., intersection negotiation). One study[20] argued that this approach conflates common errors and more-hazardous errors that indicate declines in driving fitness. Acknowledging this concern, on-road performance was assessed in a sample of healthy older adults in three ways: hazardous violations, total points accumulated, and global pass–fail assessments.[14]

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The present study had two goals. The first was to assess the predictive validity of the Roadwise Review and the HPT in a sample of cognitively impaired older adults, using several measures of on-road performance. The second was to examine which combinations of tests would best predict on-road performance.

METHODS

Participants

Sixty-five individuals (46 male, 19 female) who had a valid driver's license and at least 20/50 distance acuity were recruited as part of a larger project on predicting driving safety. They were recruited through doctor's referrals because of a diagnosis of cognitive impairment (e.g., mild cognitive impairment, early-stage Alzheimer's, n = 19) and from community organizations (n = 46). Cognitive impairment was screened for using the Mini-Mental State Examination (MMSE), with a cutoff of 26 or less (out of 30 points), which resulted in a sample of 43 cognitively impaired older adults, who were included in all analyses. Summary demographic data for these individuals are presented in Table 1.

All participants received $40 for their involvement in the study. The Conjoint Faculties Research Ethics Board of the University of Calgary approved this study (File 7207).

MATERIALS AND PROCEDURE

The study was completed in two sessions. The first laboratory session lasted approximately 2 hours. Participants provided demographic information (Table 1) and took tests of visual acuity (Landolt C), contrast sensitivity (VISTECH 6500),[21] and color vision (Farnsworth D-15 Color Test).[22] Next, they completed the MMSE[23,24] and the commercially available version of the Roadwise Review, which consists of eight subtests that appear in fixed order: leg strength and general mobility, head and neck flexibility, high-contrast visual acuity, low-contrast visual acuity, visualizing missing information, information processing speed (UFOV), visual search, and working memory. Finally, participants were given a brief HPT, a series of 26 silent driving scenes, 17 containing a traffic conflict that required an evasive action such as slowing, stopping, or swerving to avoid a collision with a road user or stationary object. The remaining nine scenes had no traffic conflict and were included to moderate participants' criterion for responding. Further details have been previously published.[14]

During the second session, participants took the on-road driving evaluation, similar to that used for a general driving examination. The route took participants through a mixed residential and commercial area, was 18 km long, and lasted between 35 and 45 minutes. Trained driving instructors monitored and evaluated performance.

Initial scoring of on-road performance was that used for a general license in Alberta, Canada, and included evaluation of controls, parking, lane control, intersections, traffic lights, right of way, speed, and automatic disqualifications. Drivers failed the examination if they exceeded 75 points. Some infractions warranted automatic failure for errors in categories including violations related to right of way or being unable to perform a skill or maneuver, which were used to represent "serious safety errors."

Table 1. Demographic Characteristics and Vision Tests, Roadwise Review, Hazard Perception Test (HPT), and On-Road Evaluation Results

Variable	Value
Demographic	
Sex, n	
Male	33
Female	10
Age, mean (range)	74.0 (55–90)
Education, years, mean (range)	13.9 (8–20)
Health Ratings (Scale of 1–5), mean (range)	3.9 (2–5)
Mini-Mental State Examination score (out of 30), mean (range)	23.6 (16–26)
Number of prescribed medications, mean (range)	2.6 (0–12)
Vision tests	
Color vision problems, n	
Yes	33
No	10
Acuity, minutes of arc, mean (range)	1.9 (1–5)
Vistech, 1/contrast threshold, mean (range)	
1.5	51.3 (20–170)
3.0	95.3 (24–220)
6.0	80.3 (5–260)
12	34.0 (0–125)
18	11.3 (0–90)
Roadwise Review	
Leg strength and general mobility, seconds, mean (range)	6.1 (4–11)
Head and neck flexibility, n	
Pass	20
Fail	23
High-contrast visual acuity, n	
Pass	41
Fail	2
Low-contrast visual acuity, n	
Pass	40
Fail	3
Visualizing missing information, number correct, mean (range)	4.1 (0–10)
Visual information processing speed, seconds, mean (range)	275.4 (100–790)
Visual search, seconds, mean (range)	153.2 (66–351)
Working memory, number correct, mean (range)	1.2 (0–3)
HPT reaction time, seconds, mean (range)	5.6 (1.7–16.4)
On-road evaluation, mean (range)	
Points	86.7 (25–190)
Number of disqualifications	2.1 (0–6)

RESULTS

Participant demographic characteristics are comparable with those reported previously,[19] except for MMSE scores (mean 23.6), which clearly placed the sample in the range indicative of cognitive impairment.[25] Descriptive statistics for test variables and on-road evaluation are presented in Table 1. Zero-order correlations between measures are shown in Table 2.

Table 2. Zero-Order Correlations Between Roadwise Review Raw Scores, Hazard Perception Test (HPT), and Categories of On-Road Evaluation

			On-Road Categories							
Variable	HPT (RT)	Total Hazardous Errors	Total Points	Controls	Parking, Starting, Backing	Lane Driving	Intersections, Turns	Traffic Lights, Signs	Right of Way	Speed
Roadwise Review										
Leg strength and general mobility	0.06	0.19	−0.06	−0.05	0.16	−0.11	−0.08	0.13	0.12	−0.07
Head and neck flexibility	0.04	0.06	−0.09	−0.28	−0.02	0.02	−0.25	−0.09	0.05	0.04
High-contrast visual acuity	−0.09	−0.23	−0.18	−0.11	−0.05	−0.11	−0.14	0.05	−0.10	−0.10
Low-contrast visual acuity	−0.02	−0.06	−0.18	−0.13	−0.06	−0.21	−0.15	0.32[a]	−0.12	−0.01
Visualizing missing information	0.28	0.20	−0.04	−0.21	−0.01	−0.18	0.03	0.07	0.14	0.10
Visual information and processing speed	0.11	0.04	−0.09	−0.09	−0.12	0.03	−0.13	0.00	0.12	−0.25
Visual search	0.21	0.05	−0.12	−0.16	−0.07	−0.14	−0.05	0.23	0.13	−0.18
Working memory	0.25	0.16	0.10	−0.01	0.05	0.16	−0.01	0.11	.05	−0.02
HPT RT	—	0.32[a]	0.31[a]	0.06	0.39[b]	0.14	0.19	−0.05	0.24	0.25
Number of medications	−0.19	0.13	0.14	−0.23	−0.21	0.01	0.00	0.23	−0.12	0.37[b]
Mini-Mental State Examination score	−0.17	−0.32[a]	−0.19	0.09	−0.17	−0.16	0.02	−0.25	0.24	−0.17

$P <$ [a].05, [b].01.
RT = reaction time.

Table 3. Sensitivity, Specificity, and Area Under the Receiver Operating Characteristic Curve (AUC) for the Subtests of the Roadwise Review

Roadwise Review Subtests	Sensitivity	Specificity	AUC
	%		
Leg strength	32	92	0.60
Head and neck flexibility	55	50	0.52
High-contrast visual acuity	0	83	0.42
Low-contrast visual acuity	3	83	0.43
Visualizing missing information	52	50	0.50
Visual information processing speed	26	92	0.52
Visual search	94	42	0.54
Working memory	65	50	0.56

Raw scores on the Roadwise Review were not predictive of the number of disqualifications (F (8, 34) = 0.96, P = .48, coefficient of determination (R^2) = 0.18) or accumulated points on the driving evaluation (F (8, 34) = 0.62, P = .76, R^2 = 0.13). Neither did they significantly increase the pass–fail classification accuracy from the constant-only model (χ^2 (8) = 8.72, P = .37, Nagelkerke R^2 (Nag) = 0.26). Together, the eight subtests of the Roadwise Review had a sensitivity of 68% and a specificity of 75% (area under the receiver operating characteristic curve (AUC) = 0.75). (See Table 3 for the performance of individual tests.)

The HPT predicted the number of disqualifications (F (1, 41) = 4.75, P = .03, R^2 = 0.10), points accumulated (F (1, 41) = 4.37, P = .04, R^2 = 0.10), and passing or failing the driving evaluation (χ^2 (1) = 4.93, P = .03, Nag = 0.16), although the overall classification accuracy did not change from the constant only model of 72.1%. The HPT had a sensitivity of 74% and a specificity of 75% (AUC = 0.71).

In line with a previous study,[11] it was determined whether the HPT, the measure of leg strength from the Roadwise Review, and color vision would accurately predict a pass–fail outcome. The three measures significantly increased the classification accuracy (χ^2 (3) = 8.48, P = .04, Nag = 0.26) and yielded a sensitivity of 90% but a specificity of only 50% (AUC = 0.77).

Which combinations of laboratory tests best predicted whether a driver passed or failed the on-road evaluation was then determined. Using the HPT, leg strength, high- and low-contrast visual acuity, working memory, and number of medications yielded an overall classification accuracy of 83.7% (χ^2 (6) = 13.86, P = .03, Nag = 0.40), a sensitivity of 71%, and a specificity of 75% (AUC = 0.80).

DISCUSSION

On its own, the Roadwise Review did not predict on-road performance using any outcome variable. Reaction time on the HPT predicted all outcome measures. By combining several laboratory-based measures, it was possible to increase the sensitivity and specificity of the model to the level needed to make decisions about fitness to drive, comparable with the sensitivity and specificity of other recent studies.[14,26] Although these tests are not currently available for mass testing, as in a government-based licensing facility, it is estimated that 30 minutes would be required per person.

It is not surprising that a battery measuring different abilities is needed to predict driving outcomes. Driving is a complex task that requires intact and efficiently operating

physical, perceptual, and cognitive systems that support motor responses, spatial resolution, peripheral vision, movement perception, working memory, attention and decision-making. The tests that best predicted on-road performance measure these abilities, some from the Roadwise Review, but including the HPT, which is more directly related to attention, search, and decision-making under timed conditions similar to those in driving.

The present study had a number of strengths. First, the on-road evaluation was virtually identical to the standard evaluations currently used to assess licensure. This consistency aids in the generalizability of the findings beyond that of studies using nonconventional measures (e.g., reaction time to a single emergency).

Second, this is the first study to examine the Roadwise Review and the HPT together in a sample of cognitively impaired older adults, which allowed how these predictors perform singly and in combination to be seen. The HPT was the best single predictor of on-road driving performance, but neither the HPT nor the Roadwise Review alone worked particularly well. This outcome is consistent with earlier work involving healthy older drivers.[14,26]

Third, this study examined multiple predictors in relation to three different assessments of on-road performance. This approach affords a better understanding of how the predictors relate to on-road performance. For example, the HPT was related to total number of disqualifications, as well as to parking, starting, and backing up on the driver examination checklist. The total number of disqualifications can be thought of as "serious safety errors," whereas parking, starting, and backing up involve observation and judgment. Given this pattern of correlations, it is reasonable to assert that the HPT measures not only a driver's reaction time to hazardous situations, but also a driver's skills in observation and judgment.

A convenience sample recruited from community organizations and physician referrals was relied on. Future research should replicate this work in other groups of more representative and clearly defined cognitively impaired participants. Additionally, it was possible to assess on-road performance only when participants were aware that they were being evaluated. It is not clear that such a "one-shot" indicator of performance is the best indicator of driving safety or collision risk. Certainly a more-naturalistic, longitudinal, prospective driving study would help uncover those screening tests with the most utility for assessing fitness to drive.

Accurately predicting who is safe to drive and who is not is an increasingly important challenge as the older driver population continues to grow and perhaps most challenging when older drivers have cognitive impairment. Results of the present study suggest that predicting who is safe to drive is itself a complex task that requires multiple predictors in impaired populations.[27] Future work will need to determine how these tests can be used with other information (e.g., medical history) to yield better determinations of driving fitness.

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