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Determinants of On-road Driving in Multiple Sclerosis

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1 Abstract

2 *Objective:* To investigate the cognitive, visual, and motor deficits underlying poor performance
3 on different dimensions of on-road driving in individuals with multiple sclerosis (MS).

4 *Design:* Prospective cross-sectional study

5 *Setting:* MS Clinic and Driving Simulator Lab

6 *Participants:* A total of 102 active drivers with various types of MS.

7 *Interventions:* Not applicable

8 Main outcome measure: Off-road cognitive, visual and motor functions, as well as 13 specific
9 driving skills. These skills were categorized into hierarchic clusters of operational, tactical,
10 visuo-integrative, and mixed driving. Stepwise regression analysis was employed to determine
11 the off-road functions influencing performance on the on-road test and each cluster.

12 *Results:* Visuospatial function ($p=0.002$), inhibition ($p=0.008$), binocular acuity ($p=0.04$),
13 vertical visual field ($p=0.02$), and stereopsis ($p=0.03$) best determined variance in total on-road
14 score (unadjusted $R^2=0.37$). Attentional shift ($p=0.0004$), stereopsis ($p=0.007$), glare recovery
15 ($p=0.047$), and use of assistive devices ($p=0.03$) best predicted the operational cluster
16 (unadjusted $R^2=0.28$). Visuospatial function ($p=0.002$), inhibition ($p=0.002$), reasoning
17 ($p=0.003$), binocular acuity ($p=0.04$), and stereopsis ($p=0.005$) best determined the tactical
18 cluster (unadjusted $R^2=0.41$). The visuo-integrative model (unadjusted $R^2=0.12$) comprised
19 binocular acuity ($p=0.007$) and stereopsis ($p=0.045$). Inhibition ($p=0.0001$) and binocular acuity
20 ($p=0.001$) provided the best model of the mixed cluster (unadjusted $R^2=0.25$).

Conclusions: Our results provide more insights into the specific impairments that influence different dimensions of on-road driving and may be used as a framework for targeted driving intervention programs in MS.

Key words: multiple sclerosis; vision; neuropsychology; rehabilitation; driving

Abbreviations:

DA, divided attention

EDSS, Expanded Disability Status Scale

MS, multiple sclerosis

MMSE, Mini-Mental State Examination

RA, risk assessment

ROCF, Rey Osterrieth Complex Figure

PASAT, paced auditory serial addition test

SA, selective attention

SDSA, stroke drivers screening assessment

SDMT, symbol digit modalities Test

SOP, speed of processing

TMT, trail making test

TRIP, test ride for investigating practical fitness-to-drive

UFOV, Useful Field of View

VIF, variance inflation factor

Introduction

The cognitive, visual, motor, and behavioral impairments associated with multiple sclerosis (MS) eventually affect the ability to drive safely.¹ Nevertheless, about 77% of individuals with MS continue driving after diagnosis.² Those who continue to drive do so less frequently than drivers with no neurological conditions,² and are at an increased risk for car crashes.³

Between 6% and 38% of drivers with MS fail a formal road test.^{1,4-7} Yet, these studies used a dichotomous decision of fitness-to-drive as the main outcome measure which does not reflect the different skill set needed to safely drive a car in a highly interactive traffic situation.^{1,4-6} The road test consists of different sections assessing distinct driving skills.⁸ Previous studies in drivers with other neurological conditions found that distinct cognitive, visual, and motor functions impact different dimensions of on-road driving performance.⁹⁻¹³ In Parkinson's disease, severity of motor symptoms and slow reaction time correlated with operational driving skills such as maintaining lane position, whereas cognitive functions related to more complex driving skills including turning left.¹¹

Understanding which cognitive, motor, and visual functions affect specific domains of on-road driving can inform the design of off-road screening tests for evaluation of fitness-to-drive and interventions for specific driving difficulties in MS. Therefore, the aim of this study was to determine the critical impairments in cognitive, visual, and motor functions that lead to poor on-

road driving performance in MS. Similar to our work in other neurological conditions,^{9,11,13,14} we hypothesized that visual functions will impact all aspects of on-road driving, motor and cognitive functions will influence basic on-road driving skills, whereas cognitive functions will determine complex on-road driving skills in MS.

Methods

Subjects

Participants were recruited from the Andrew C. Carlos MS Institute at Shepherd Center in Atlanta, GA and Augusta University MS Center in Augusta, GA from August 2013 to October 2015. Inclusion criteria were (1) diagnosis of MS; (2) scores on the Expanded Disability Status Scale (EDSS) between 1 and 7;¹⁵ (3) age between 25-75 years; (4) valid driver's license; (5) ≥ 5 years driving experience; (6) drive at least once a month in the previous year; and (7) meet the minimum visual requirements to drive in accordance with GA laws (binocular acuity $\geq 20/60$ and peripheral vision ≥ 140 degrees). Exclusion criteria were (1) score < 24 on Mini Mental State Examination (MMSE);¹⁶ (2) fluctuations in medication and dosage in the month preceding the study; (3) exacerbation of symptoms within a month preceding the study; and (4) any other neurological condition, acute psychiatric disorder, or drug and alcohol abuse as determined by the referring neurologist.

All study protocols were approved by the Institutions' Review Boards. Written informed consent was obtained.

Off-road test battery

Demographic, clinical, and driving characteristics. Age, gender, education, disease duration, disease severity (EDSS), type of MS (relapsing-remitting; primary progressive; secondary progressive), driving experience, annual mileage, and number of traffic tickets and crashes in the last 5 years were collected. We also administered the Hospital Anxiety and Depression Scale (HADS)¹⁷ and the Modified Fatigue Impact Scale (MFIS).¹⁸

Cognitive tests. The cognitive tests are widely used in MS research, evaluate different cognitive domains, and have been found to predict fitness-to-drive in previous research.^{1,6,10,19-21}

The Useful Field of View (UFOV) consists of three subtests that evaluate speed of processing (SOP), divided attention (DA), and selective attention (SA) in milliseconds.^a The risk assessment (RA) score for prospective car crashes ranges from 1 (very low) to 5 (very high).²²

The Rey Osterrieth Complex Figure (ROCF)–copy test measures visuospatial and visuoconstructive abilities on a score ranging from 0 to 36.²³

The Symbol Digit Modalities Test (SDMT) evaluates visual search and working memory.

Number of correct responses in 90 seconds was the outcome variable.²⁴

The Trail Making Test part A (TMT A) assesses visuomotor tracking and working memory. The TMT B additionally evaluates attentional shift. Time to completion and number of errors were recorded.²⁵

The Stroop test included the color, word, and color-word subtests. The color and word subtests evaluate speed of processing. The color-word subtest assesses response inhibition and cognitive flexibility. The number of errors in a time limit of 45 seconds was the main outcome.

The Stroke Driver Screening Assessment (SDSA) for MS²⁰ consists of four tests. The dot cancellation test measures visual scanning and sustained attention. Time to completion and number of errors were recorded. The directions and compass tests measure reasoning skills. Correct answers were scored on a scale ranging from 2 to 32. The road sign recognition test evaluates visual comprehension and traffic knowledge. The scale ranges from 0 to 12.

The Paced Auditory Serial Addition Test (PASAT-3 seconds) evaluates working memory, auditory information processing speed and flexibility, as well as arithmetic ability. Number of correct responses was recorded.²⁶

Visual tests. Scores on binocular acuity (far, mid (26''), and near distance), peripheral vision (horizontal and vertical), color perception (red/green and blue/violet), stereopsis (depth perception), glare recovery, and contrast sensitivity were dichotomized into pass-fail scores according to the Keystone Vision Screener cut-off values.^b

Motor tests. The motor assessment included the 25-foot walk test,²⁶ the 9-hole pegtest,²⁶ and the Barthel Index.²⁷ The use of assistive devices (yes/no) was also documented.

Road test

The main outcome was score on the Test Ride for Investigating Practical fitness-to-drive (TRIP).^{8,28} The TRIP consists of 13 items and 49 sub-items, each scored on a 4-point ordinal scale. The total TRIP score was the sum of all item scores and ranged from 49 to 196. All 13 items were mapped onto a theoretical framework of hierarchic driving skills according to Michon²⁹ and adapted by De Raedt and Ponjaert-Kristofferson.²⁸ The operational cluster comprised lateral position on the road at speed (I) below and (II) above 45 m/h, and (III) mechanical operations.^{28,29} The tactical cluster consisted of speed adaptations at speed (IV) below and (V) above 45 m/h, headway distance to the lead car at speed below (VI) and (VII) above 45 m/h, and (VIII) lane position change.^{28,29} The visuo-integrative cluster included (IX) anticipation and perception of road signs and traffic signals, (X) visual behavior and communication with other road users, and (XI) traffic insight, understanding, and quality of

traffic participation.²⁸ Finally, the mixed cluster included the items (XII) joining the traffic stream and (XIII) turning left.²⁸ The items in the mixed cluster encompassed a combination of operational, tactical, and visuo-integrative skills. For example, left-turn maneuvers were rated on operational skills (e.g., signal indicator use); tactical skills (e.g., gap acceptance to opposing traffic); and visuo-integrative skills (e.g., checking mirrors and blind spots).

Each participant's practical fitness-to-drive was evaluated in a vehicle with automatic transmission, adapted with dual controls, and registered with the GA Department of Driver Services. Assistive devices were installed in the car if needed (e.g., spinner knob). The road test course traversed rural, urban, and interstate roadways and took approximately 45 minutes to complete. The TRIP checklist was administered immediately after completion of the road test by certified driving instructors or driving rehabilitation specialists. All driving assessors attended a one-day workshop where the reliability of TRIP scoring was established through video review of four drives.

Statistical analysis

Kolmogorov-Smirnov tests were used to determine normality of the variables. Pearson correlations (r) were calculated between on-road scores and normally distributed off-road variables. On-road scores were correlated with off-road ordinal variables and not normally distributed ratio variables using Spearman rho (ρ). Correlations (r/ρ) were considered weak below 0.10, moderate between 0.10 and 0.49 and strong between 0.50 and 1.00.³⁰ Independent

variables were entered into a multivariate stepwise linear regression analyses with a select entry (p<0.15) and retain (p<0.05) level for each of the five on-road models: (1) total TRIP score; (2) operational cluster; (3) tactical cluster; (4) visuo-integrative cluster; and (5) mixed cluster. We verified the collinearity between independent variables by correlation analysis ($r/p > 0.40$) and calculating variance inflation factors (VIF). A VIF score of 10 or higher was considered to indicate substantial collinearity.³¹ P values < 0.05 were considered significant. All statistical analyses were performed with SAS®, version 9.4.^c

Results

Table 1 shows that the majority (86%) of the 102 participants was female and presented with no to limited functional (e.g., Barthel Index) and cognitive disability (e.g., MMSE). Eight (8%) drivers required car modifications (spinner knob or hand controls). Scores on the cognitive tests are presented in Supplementary Table 1.

Insert Table 1 here

Total on-road score

Overall, most drivers with MS achieved submaximal performance on the road test (Table 2).

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191

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Insert Table 2 here

193

194 Weak to moderate correlations were found between performance in off-road tests and total TRIP
195 scores (Table 3). The magnitude of correlations of the significant variables ranged between 0.21
196 (UFOV RA and Stroop color-word) and 0.40 (traffic tickets and TMT B time). Among the
197 descriptive variables, education and number of traffic tickets correlated significantly with total
198 TRIP scores. In the cognitive domain, all variables were associated with total TRIP scores,
199 except for MMSE, Stroop color and word subtests, and number of errors on TMT A, TMT B,
200 and dot cancellation. In the visual domain, binocular acuity at mid-distance, peripheral visual
201 field, and stereopsis correlated with on-road scores. The 9-hole peg test was the only variable in
202 the motor domain that correlated with total TRIP scores.

203

204

Insert Table 3 here

205

206 Regression analysis showed that total TRIP scores were determined by a combination of five
207 cognitive and visual functions: ROCF, Stroop color-word, binocular acuity at mid-distance,
208 vertical visual field, and stereopsis (Table 4).

209

Insert Table 4 here

Operational cluster

Table 3 shows that the magnitude of significant correlations between off-road variables and the operational cluster ranged between 0.21 (TMT B errors and UFOV SA) and 0.37 (TMT B time and 9-hole peg test).

The regression analysis constituted a multidimensional model of four variables in the cognitive, visual, and motor domains to determine scores on the operational cluster: TMT B errors, stereopsis, glare recovery, and use of assistive devices (Table 4).

Tactical cluster

Table 3 shows that the magnitude of significant correlations between off-road variables and the tactical cluster ranged between 0.20 (ROCF) and 0.32 (digit symbol).

A combination of ROCF, directions, Stroop color-word, mid-distance acuity, and stereopsis explained 41% of the variance in the tactical driving cluster (Table 4).

Visuo-integrative cluster

Table 3 shows that the magnitude of significant correlations between off-road variables and the visuo-integrative cluster ranged between 0.22 (education and road sign recognition) and 0.32 (TMT B time and vertical visual field).

Only binocular acuity at mid-distance and stereopsis were retained in the model, explaining 12% of the variance in the visuo-integrative cluster (Table 4).

Mixed cluster

The magnitude of significant correlations between off-road variables and the mixed cluster ranged between 0.22 (road sign recognition) and 0.36 (mid-distance acuity). Compared with the other on-road clusters, fewer off-road variables correlated significantly with the mixed cluster (Table 3).

Only binocular acuity at mid-distance and Stroop color-word were retained in the multivariate regression analysis, explaining 25% of the variance in the mixed cluster (Table 4).

Supplementary Table 2 shows the correlation matrix between the cognitive, visual, and motor tests and the 13 on-road items.

Discussion

This study focused on identifying the critical impairments in cognitive, visual, and motor functions underlying poor on-road driving in MS. To capture the different dimensions of on-road driving, we mapped the TRIP items onto an existing theoretic framework of hierarchic driving skill consisting of operational, tactical, visuo-integrative, and mixed clusters.^{28,29}

This cohort of drivers with MS performed equally well on the same checklist of on-road driving performance used to investigate driving difficulties in Parkinson's disease, stroke, and Huntington's disease.^{13,14,32} Similar to these studies, our results support the notion that visual, cognitive, and motor impairments differently affect distinct on-road driving skills.^{10,11,13}

General disease descriptors (e.g., disease duration, EDSS) or demographic information (e.g., age) were not retained as determinants in any of the on-road driving models once cognitive, visual, and motor functions were added. This finding extends empirical evidence that disease status and age alone fail to inform clinical decisions regarding fitness-to-drive in MS.

Visuospatial ability (ROCF), response inhibition (Stroop color-word) and visual functions (mid-

distance binocular acuity, vertical visual field, and stereopsis) constituted the best model to explain total on-road scores in drivers with MS. Two systematic reviews recommended ROCF as a valid screening tool for fitness-to-drive after stroke.^{33,34} Akinwuntan et al. found the ROCF to be univariately correlated with pass-fail driving status in MS.¹ Stroop color-word reflects executive functions such as response inhibition, which has shown to be impaired in MS.^{35,36}

Total on-road scores were also determined by tests assessing mid-distance binocular acuity, vertical visual field, and stereopsis, which highlight the importance of visual functions for driving. About 38% of all states rely solely on visual criteria to determine medical clearance, despite lack of evidence of a relationship between visual acuity and car crashes in the general population.³⁷ Yet, Shultheis et al. failed to find significant associations between visual acuity, horizontal visual field and driving outcomes in MS.³⁸ The inclusion of other visual tests and the use of a standardized on-road test rather than self-report of driving behavior may be the reason for the inconsistency of our results with previous findings.³⁸

Visual functions continued to be important determinants of each on-road driving cluster, emphasizing the importance of intact vision across all hierarchic levels of driving skill. Mid-distance acuity and peripheral visual field were even sole determinants of the visuo-integrative cluster. By contrast, motor functions, indexed by the use of assistive devices, in combination with shifting of attention, stereopsis, and glare recovery, showed to correlate only with operational driving items in the multivariate model. Operational driving skills require intact motor functions to operate the steering wheel and pedals and keep the car under control.²⁹

Finally, ROCF, Stroop color-word, mid-distance acuity, directions tests and stereopsis explained 41% of the total variance in the tactical cluster, which was higher than any of the other clusters of driving skill. These findings reveal the major role of cognitive functions, especially visuospatial (ROCF) and executive functions (Stroop color-word, directions) in tactical driving skills, such as speed adaptation or lane changing. Other studies support the use of the directions test to predict fitness-to-drive in MS.^{6,19,20}

Clinically, this research highlights the importance of assessing specific cognitive and visual functions to determine driving abilities in individuals with MS. However, some neuropsychological tests widely used in the clinic (MMSE, PASAT) have limited ability to predict on-road driving. We recommend the use of ROCF and the Stroop test to assess visuospatial functions and response inhibition as well as stereopsis and vertical visual field to assess visual functions in drivers with MS.

Detailed study of the factors underlying impaired on-road driving in MS also opens avenues for rehabilitation. Cognitive rehabilitation shows promising evidence to improve attention, executive functions, and memory in MS.³⁹ Remedial interventions to improve these cognitive functions may translate to improvements in on-road driving. Yet, the few intervention studies that focused on remedial training of driving-related cognitive functions in patients with stroke found limited carry-over to on-road driving.⁴⁰ Our results suggest that targeted training of visuomotor tracking and attentional shift may result in improvements in operational driving skills, whereas training of

visuospatial functions and response inhibition may transfer to improvements in tactical driving skills.

Visual scanning strategies, extra mirrors, or corrective glasses may compensate for visual field and binocular acuity loss whereas teaching drivers to maintain proper headway distance may help with impairments in stereopsis. These compensational strategies may result in improvements in tactical, visuo-integrative, and mixed driving skills. Physical therapy can help to improve performance on operational driving skills such as applying the emergency brake or controlling the steering wheel. Alternatively, the car may be equipped with a spinner knob, hand brakes, or left sided gas pedal to compensate for muscle weakness or spasticity. None of these proposed interventions have been tested in a controlled experiment. One pilot study found that five hours of simulator-based driving training improved working memory, visual scanning, color perception, and fatigue in 36 individuals with relapsing-remitting MS.⁴¹

The strength of the current study is that we included a broad off-road assessment battery to determine performance in hierarchic driving clusters in a large sample of active drivers with MS. Our findings lend to a theoretic framework for remedial training of targeted driving skills.

Study limitations

The study has several limitations, including the lack of an age- and sex-matched control group.

We therefore cannot determine whether this cohort of drivers with MS showed impaired driving skills compared to controls and whether the determinants of on-road driving are inherent to MS. However, for the clinical purpose of this study, i.e., to provide a framework for driving screening and interventions in individuals with MS, a comparison to a control group was not deemed necessary.

Similar to previous studies,^{13,14,19,32} the variance explained by the visual, cognitive, and motor tests remained moderate, even though cognitive and visual tests that were underexplored in previous studies were added to this broad off-road assessment battery. One of the reasons for the moderate variance explained by the cognitive functions may be that this cohort of drivers with MS did not show substantial cognitive deficits. They achieved similar scores on the MMSE, PASAT, TMT A and B, and ROCF when compared to norm values.⁴²⁻⁴⁵ Since we included a broad assessment battery, some of the analyses were exploratory. For this purpose, we did not control for multiple comparisons.

Although the TRIP is a reliable⁸ and valid⁴⁶ questionnaire widely used to assess practical fitness-to-drive, we do not have any quantitative measures from the vehicle (e.g. driving speed, lane position). Further studies should consider the inclusion of quantitative measures of naturalistic driving.

Conclusions

Our findings showed that on-road driving performance in MS is affected by a combination of cognitive, visual, and, to a lesser extent, motor functions. We recommend that screening tests should broadly assess multiple domains of cognitive and visual sensory functions rather than narrowly targeting one single domain. A detailed decomposition of the critical cognitive, visual or motor impairments underlying impaired performance on different hierarchic layers of driving in MS may provide a framework of targeted rehabilitation interventions. These intervention strategies should be tested in a randomized controlled trial.

Suppliers

- a. Useful Field of View, Visual Awareness Research Group, Inc, Punta Gorda, FL.
- b. Keystone Vision Screener, Keystone View, Reno, NV.
- c. SAS, version 9.1, SAS Institute, Inc, Cary, NC.

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Table 1. Demographic and clinical characteristics (n =102)

Variable	Mean (SD)	Range
Age, years	47.91 (8.71)	25 – 65
Driving experience, years	31.06 (8.87)	10 – 49
	Median (Q1 – Q3)	
Annual mileage, 1000 miles/y	2.80 (1.04 – 10.00)	0.2 – 55
Tickets in last five years, n	0 (0 – 1)	0 – 4
Crashes in last five years, n	1 (0 – 1)	0 – 2
EDSS, /10	5 (4 – 7)	2 – 7
Disease duration, y	9 (5 – 14)	0 – 37
Barthel Index, /100	95 (90 – 100)	65 – 100
MMSE, /30	30 (30 – 30)	24 – 30
HADS depression, / 21	5 (2 – 7)	0 – 18
HADS, anxiety, / 21	7 (4 – 10)	0 – 19
MFIS, /84	39.77 (15.88)	29 – 51
	N (%)	
Sex, female	88 (86)	N/A
Type of MS (RRMS; PPMS; unknown)	91 (89); 10 (10); 1 (1)	N/A

Abbreviations: EDSS, Expanded Disability Status Scale; HADS, Hospital Anxiety and Depression Scale; MMSE, Mini-Mental State Examination; N/A, not applicable; RRMS, relapsing remitting multiple sclerosis; PPMS; primary progressive multiple sclerosis.

Table 2. Performance in Test Ride for Investigating Practical fitness-to-drive (n =102)

Variable	Mean (SD)	Scale range
<i>Total on-road score</i>	184.15 (13.48)	49 – 196
<i>Operational cluster</i>	24.57 (5.04)	7 – 28
I. Lateral position on the road at speed < 45 mph	6.39 (2.33)	2 – 8
II. Lateral position on the road at speed > 45 mph	6.76 (2.21)	2 – 8
III. Mechanical operations	11.49 (1.38)	3 – 12
<i>Tactical cluster</i>	49.50 (3.37)	13 – 52
IV. Speed adaptations at speed < 45 mph	7.33 (1.07)	2 – 8
V. Speed adaptations at speed > 45 mph	7.09 (1.28)	2 – 8
VI. Headway distance at speed < 45 mph	7.73 (1.07)	2 – 8
VII. Headway distance at speed > 45 mph	7.81 (0.70)	2 – 8
VIII. Lane position change	19.61 (1.50)	5 – 20
<i>Visuo-integrative cluster</i>	52.61 (4.92)	14 – 56
IX. Anticipation and perception of road signs and traffic lights	15.14 (2.00)	4 – 16
X. Visual behavior and communication	30.00 (3.20)	8 – 32
XI. Traffic insight, understanding, and quality of traffic participation	7.47 (1.10)	2 – 8
<i>Mixed cluster</i>	57.46 (4.06)	15 – 60
XII. Joining the traffic stream	23.00 (2.36)	6 – 24
XIII. Turning left	34.57 (2.53)	9 – 36

Table 3. Correlation matrix of on-road total TRIP score and clusters with performance on off-road battery^a

	Total score		Operational		Tactical		Visuo-integrative		Mixed	
	r/p	p	r/p	p	r/p	p	r/p	p	r/p	p
Descriptive										
Age	-0.02	0.82	-0.01	0.92	0.06	0.55	-0.02	0.87	-0.09	0.35
Education	0.26	0.01	0.09	0.35	0.15	0.13	0.22	0.03	0.13	0.19
Disease duration	-0.07	0.50	-0.11	0.28	-0.02	0.85	-0.09	0.39	0.004	1.00
EDSS	-0.14	0.15	-0.14	0.17	-0.07	0.48	-0.03	0.74	-0.17	0.10
Type of MS	-0.04	0.66	0.06	0.58	-0.11	0.25	0.03	0.75	-0.11	0.29
HADS, depression	-0.11	0.16	-0.12	0.15	-0.11	0.16	-0.14	0.12	-0.14	0.12
HADS, anxiety	-0.11	0.19	-0.13	0.15	-0.17	0.10	-0.13	0.12	-0.17	0.10
MFIS	-0.01	0.89	-0.09	0.37	0.004	0.96	-0.02	0.86	0.09	0.40
Driving experience	0.09	0.35	0.07	0.50	0.14	0.17	0.09	0.35	0.004	0.97
Annual mileage	-0.15	0.14	0.05	0.62	-0.26	0.01	-0.14	0.19	-0.07	0.49
Traffic tickets	-0.40	<0.0001	-0.31	0.002	-0.22	0.02	-0.26	0.01	-0.24	0.01
Traffic crashes	0.007	0.94	0.07	0.48	0.03	0.77	-0.08	0.42	-0.01	0.54
Cognitive										
MMSE	0.18	0.08	0.13	0.21	0.11	0.28	0.09	0.39	0.14	0.16
UFOV, SOP	-0.23	0.02	-0.06	0.52	-0.21	0.04	-0.23	0.02	-0.15	0.15
UFOV, DA	-0.33	0.0009	-0.27	0.006	-0.19	0.06	-0.31	0.002	-0.18	0.07
UFOV, SA	-0.27	0.01	-0.21	0.03	-0.17	0.09	-0.25	0.01	-0.14	0.17
UFOV, RA	-0.21	0.03	-0.13	0.19	-0.15	0.13	-0.24	0.02	-0.14	0.16
ROCF	0.24	0.02	0.15	0.13	0.20	0.05	0.18	0.07	0.25	0.01
SDMT	0.28	0.004	0.17	0.10	0.32	0.001	0.16	0.12	0.28	0.005
TMT A, errors	0.07	0.49	0.09	0.38	0.03	0.76	0.02	0.85	0.11	0.25
TMT B, time	-0.40	<0.0001	-0.37	0.0002	-0.29	0.004	-0.32	0.001	-0.17	0.09
TMT B, errors	-0.14	0.16	-0.21	0.03	-0.04	0.72	-0.15	0.14	-0.02	0.81
Dot cancellation time	-0.23	0.02	-0.16	0.11	-0.21	0.03	-0.16	0.09	-0.17	0.09
Dot cancellation errors	-0.01	0.94	-0.005	0.96	0.13	0.21	-0.006	0.95	-0.04	0.74
Stroop color	0.09	0.39	0.12	0.25	0.06	0.57	-0.006	0.96	0.11	0.31
Stroop word	-0.15	0.17	0.11	0.3	-0.17	0.14	-0.11	0.35	-0.23	0.045
Stroop C/W	-0.21	0.04	-0.02	0.83	-0.23	0.02	-0.09	0.39	-0.22	0.03
Directions	0.28	0.004	0.17	0.10	0.31	0.001	0.15	0.12	0.28	0.005
Compass	0.29	0.004	0.30	0.002	0.29	0.003	0.15	0.12	0.17	0.09
Road Sign Recognition	0.29	0.003	0.30	0.002	0.24	0.02	0.22	0.02	0.22	0.03
PASAT	0.14	0.24	0.08	0.48	0.04	0.71	0.18	0.11	0.18	0.11
Visual										
Acuity, far	-0.04	0.70	0.006	0.95	-0.07	0.47	-0.06	0.56	-0.09	0.38
Acuity, mid	-0.30	0.003	-0.08	0.45	-0.22	0.03	-0.29	0.004	-0.36	0.0002
Acuity, near	-0.09	0.37	-0.003	0.97	0.009	0.93	-0.11	0.29	-0.20	0.05
Peripheral, horizontal VF	0.11	0.31	0.08	0.46	0.13	0.20	0.03	0.74	0.02	0.84
Peripheral, vertical VF	-0.24	0.02	-0.20	0.05	-0.15	0.14	-0.32	0.002	-0.09	0.36
Color perception, R/G	-0.14	0.18	-0.04	0.70	-0.10	0.33	-0.16	0.12	-0.17	0.10
Color perception, B/V	-0.19	0.06	-0.22	0.03	-0.07	0.50	-0.12	0.25	-0.10	0.31
Stereopsis	-0.26	0.01	-0.28	0.01	-0.26	0.01	-0.07	0.50	-0.08	0.43

Glare recovery	-0.13	0.20	-0.27	0.01	-0.15	0.14	0.04	0.71	0.05	0.62
Contrast sensitivity	-0.07	0.47	-0.16	0.12	0.006	0.96	0.06	0.53	0.006	0.95
Motor										
Barthel	-0.03	0.77	0.08	0.44	0.03	0.74	-0.07	0.50	-0.04	0.70
25-foot walk	-0.11	0.31	-0.16	0.11	-0.02	0.86	0.007	0.94	-0.09	0.33
9-hole peg dominant	-0.32	0.001	-0.37	0.0001	-0.17	0.10	-0.13	0.21	-0.17	0.08
Assistive device	-0.21	0.09	-0.24	0.02	-0.10	0.58	-0.05	0.80	-0.16	0.42

Abbreviations: B/V, blue-violet; DA, divided attention; C/W, color-word; EDSS, Expanded Disability Status Scale; HADS, Hospital Anxiety and Depression Scale; MMSE, Mini-Mental State Examination; MS, multiple sclerosis; PASAT, paced auditory serial addition test; RA, risk assessment; R/G, red/green; ROCF, Rey-Osterrieth Complex Figure; SA, selective attention; SOP, speed of processing; SDMT, symbol digit modalities test; TMT, Trail Making Test; UFOV, Useful Field Of View; VF, visual field.

Table 4. Results of the five multivariate linear regression analysis models

Dependent variable	Independent variables	beta value	t-value	p-value
Total TRIP score	ROCF	0.92	3.90	0.0002
	Stroop color-word errors	-8.30	-2.70	0.008
	Acuity mid-distance	-5.55	-2.06	0.04
	Vertical VF	-6.72	-2.43	0.02
	Stereopsis	-5.25	-2.21	0.03
Operational cluster	TMT B errors	-0.86	-3.67	0.0004
	Stereopsis	-2.90	-2.76	0.007
	Glare recovery	-3.30	-2.01	0.047
	Assistive device (yes/no)	2.65	2.24	0.03
Tactical cluster	ROCF	0.20	3.21	0.002
	Stroop color-word errors	-2.60	-3.27	0.002
	Directions	0.20	3.38	0.001
	Acuity mid-distance	-1.39	-2.05	0.04
	Stereopsis	-1.78	-2.89	0.005
Visuo-integrative cluster	Acuity mid-distance	-3.22	-2.75	0.007
	Vertical VF	-2.50	-1.82	0.045
Mixed cluster	Stroop color-word errors	-4.29	-4.06	0.0001
	Acuity mid-distance	-2.85	-3.32	0.001

Abbreviations: ROCF, Rey-Osterrieth Figure of Rey; TMT, Trail Making Test; TRIP, Test Ride

for Investigating Practical fitness-to-drive; VF, visual field