Manuscript title: Driving and off-road impairments underlying failure on road testing in Parkinson's disease

Names and institutional affiliations of the authors:

H. Devos, PhD,[1,2,3] W. Vandenberghe, MD, PhD,[4,5] M. Tant, PhD,[6] A.E. Akinwuntan, PhD, MPH,[3] W. De Weerdt, PhD,[1] A. Nieuwboer, PhD,[1] E.Y. Uc, MD[7,8]

[1] Department of Rehabilitation Sciences, KU Leuven – University of Leuven, Leuven, Belgium; [2] National Advanced Driving Simulator, University of Iowa, Iowa City, IA, USA; [3] Department of Physical Therapy, Georgia Regents University, Augusta, GA, USA; [4] Department of Neurology, University Hospitals Leuven, Leuven, Belgium; [5] Department of Neurosciences, KU Leuven – University of Leuven, Leuven, Belgium; [6] CARA Department, Belgian Road Safety Institute, Brussels, Belgium; [3] Department of Neurology, University of Iowa, Iowa City, IA, USA; [8] Neurology Service, Veterans Affairs Medical Center, Iowa City, IA, USA.

Name and address for corresponding author:

Hannes Devos

KU Leuven - University of Leuven; Faculty of Kinesiology and Rehabilitation Sciences; Department of Rehabilitation Sciences; Tervuursevest 101, Post Box 1501; BE-3001 Leuven

Tel. +32 16 32 91 20 Fax +32 16 32 91 92

E-mail: Hannes.Devos@faber.kuleuven.be

Word count: Number of characters in the title: 90; Number of words in the abstract: 247; Number of words in the body: 2,992; Number of tables: 5; Number of references: 40; Number of figures: 0

Running title. Driving skill impairments in PD

Key words. Parkinson's disease; automobile driving; cognitive assessment; visual acuity; postural instability and gait disorders

Financial disclosure/conflict of interest. The authors report no financial disclosures. The authors report no conflict of interest.

Funding sources. This study was supported by the Department of Rehabilitation Sciences of KU Leuven and CARA, Belgian Road Safety Institute. Dr. Uc is supported by a Merit Review grant from Rehabilitation Research and Development Branch, the US Department of Veterans Affairs.

ABSTRACT

Background Parkinson's disease (PD) affects driving ability. We aimed to determine the most critical impairments in specific road skills and in clinical characteristics leading to failure on a road test in PD.

Methods In this cross-sectional study, certified driving assessment experts evaluated specific driving skills in 104 active, licensed drivers with PD using a standardized, on-road checklist and issued a global decision of pass/fail. Participants also completed an off-road evaluation assessing demographic features, disease characteristics, motor function, vision, and cognition. The most important driving skills and off-road predictors of the pass/fail outcome were identified using multivariate stepwise regression analyses.

Results Eighty-six (65%) passed and 36 (35%) failed the on-road driving evaluation. Persons who failed performed worse on all on-road items. When adjusted for age and gender, poor performances on lateral positioning at low speed, speed adaptations at high speed, and left turning maneuvers yielded the best model that determined the pass/fail decision ($R^2 = 0.56$). The fail group performed poorer on all motor, visual, and cognitive tests. Measures of visual scanning, motor severity, PD subtype, visual acuity, executive functions, and divided attention were independent predictors of pass/fail decisions in the multivariate model ($R^2 = 0.60$).

Conclusions Our study demonstrated that failure on a road test in PD is determined by impairments in specific driving skills and associated with deficits in motor, visual, executive, and visuospatial functions. These findings point to specific driving and off-road impairments that can be targeted in multimodal rehabilitation programs for drivers with PD.

INTRODUCTION

Driving a car requires intact motor, visual, and cognitive processes.(1) These functions can be compromised in Parkinson's disease (PD), leading to a higher risk of failing an official road test. Between 28%(2) and 56%(3) of drivers with PD fail a fitness to drive evaluation compared to 0%(4) to 12%(3) of age-matched drivers without PD.

Drivers with PD exhibit difficulties with various on-road driving skills that require specific motor actions(4) (steering accuracy, lane positioning), trunk and head mobility(4, 5) (checking blind spot, back and side mirrors), attention(6) (driving under distraction), visual perception and scanning(7) (identification of traffic signs and landmarks), memory retrieval(8) (navigation), and rapid decision making at T junctions.(4, 9) Yet, it is unclear which specific driving impairments independently determine failure on road testing. The identification of these skills is essential to understand the mechanisms of unsafe driving and to develop a conceptual framework for driving rehabilitation in PD.

In an evidence-based review, motor scores of the Unified Parkinson's Disease Rating Scale (UPDRS III), functional reach, contrast sensitivity, Trail Making Test B, Useful Field of View (UFOV), and Rey-Osterrieth Complex Figure (ROCF) showed to be predictive of on-road performance in PD.(10) These findings indicate that impaired on-road driving ability in PD may be ascribed to a complex interplay of motor and non-motor symptoms. However, the independent effect of different off-road deficits on specific driving impairments and failure on road testing is yet to be established.(10)

The aims of this study were (1) to determine the specific on-road items that lead to failure on a road test and (2) to identify the underlying motor, visual, and cognitive skills that predict poor performance on critical driving abilities and overall failure on road testing in PD.

METHODS

Participants. Persons with PD were recruited from 2006 to 2012 through the Movement Disorders Clinic of the University Hospitals Leuven and the Center for Evaluation of Fitness to drive (CARA) of the Belgian Road Safety Institute. Participants recruited from the Clinic constituted a consecutive sample without apparent driving problems, whereas subjects recruited from CARA were referred for an on-road evaluation because of concerns with driving. The expert panel at CARA rendered a multidisciplinary decision on participants' fitness to drive based on road test performance and off-road abilities (e.g., motor, visual, cognitive testing).(2, 11) In this study, we used the unpublished data of the CARA evaluation to investigate the mechanisms underlying failure on the road test.

Inclusion criteria were (I) valid driver's license before diagnosis, (II) driving at least 300 km in the previous year, (III) Hoehn and Yahr (H&Y) 'on' stage 1 – 3, (IV) a maximum score of 1 on the Clinical Dementia Rating (CDR) scale(12) in accordance with the guidelines on driving and dementia,(13) and (V) minimum binocular acuity of 20/40 as stipulated by Belgian law. Participants were excluded if they had (I) deep brain stimulation, (II) unpredictable motor fluctuations, and (III) any comorbidity hindering driving.

Out of 123 persons who met the eligibility criteria, 14 declined participation, three withdrew consent, and two dropped out before testing due to medical reasons. Thus, 104 persons (63 from

the Clinic and 41 from CARA) took part in the study. Testing started approximately 30 to 45 minutes after medication intake to minimize the effect of predictable wearing-off on test results and occurred in random sequence at two different locations on two separate days. Demographic variables, disease characteristics, and driving history were collected at the University Hospitals Leuven. The off-road battery and on-road test at CARA took 3 to 4 hours to complete. The median (Q1 – Q3) time interval between assessments was 17 (4 – 32) days. The study was approved by the local ethics committee. All participants signed the informed consent form.

Demographic, driving, and disease characteristics. Demographic characteristics such as gender, age, and years of education were documented. Participant's self-appraisal of driving fitness, driving experience, driving exposure, and number of traffic tickets and crashes in the 5 years prior to testing composed the driving survey. Disease characteristics included disease duration, H&Y 'on' score, Epworth Sleepiness Scale,(14) CDR,(12) and UPDRS II (activities of the daily living).(15) PD medication intake was collected including levodopa-equivalent daily dosage (LED),(16) and use of amantadine, MAO-B inhibitors and anticholinergic medication.

The road test at CARA. The standardized 20-km road test started in a residential area in the vicinity of Brussels, proceeded to a 2-way, 4-lane highway section, continued to an urban section, and terminated at the evaluation center. All road tests were carried out in an Opel Astra, equipped with dual controls to ensure standardization and safety, by a team of four occupational or physical therapists certified to conduct driving evaluations. The assessor communicated with the participants at regular time intervals to evaluate the effect of distraction on driving ability. The on-road assessor was blind to participants' results on the neuropsychological test battery.

The Test Ride for Investigating Practical fitness to drive (TRIP) checklist was used to record participants' driving performance immediately after completion of the road test. The TRIP has established reliability and validity,(17) and has been used to determine driving deficits in neurodegenerative disorders.(2, 11, 18) The TRIP consisted of 13 items of driving ability: lateral position on the road at speed (I) below and (II) above 50 km/h; (III) mechanical operations; speed adaptations at speed (IV) below and (V) above 50 km/h; gap distance at speed (VI) below and (VII) above 50 km/h; (VIII) lane position change; (IX) anticipation and perception of road signs and traffic signals; (X) visual behavior and communication; (XI) understanding, insight, and quality of traffic participation; (XII) turning left; and (XIII) merging into traffic stream. The 49 subitems of the TRIP were each scored on a 4 point ordinal scale, giving a total score range from 49 – 196. The items were categorized into 4 clusters(19) that closely resembled the hierarchic levels of driving skill.(20) The *operational* cluster (items I – III) was time-dependent (milliseconds) and relied on automatic, motor processes.(19, 20) The *tactical* cluster (items IV – VIII) reflected driving actions that needed to be executed within seconds and involved executive functions including attention, flexibility, judgment, and adaptation strategies.(19, 20) The *visuo-integrative* cluster (items IX – XI) involved visuospatial, visuoperceptual and higher-order cognitive skills.(19) The *mixed* cluster (items XII – XIII) consisted of items that integrated all abovementioned maneuvers.(19)

The pass/fail decision on the road test was the main dependent variable. Participants allocated to the pass category showed no functional deficits that interfered with on-road driving or adequate compensational strategies. Those assigned to the fail category showed poor overall performance on the TRIP evaluation or incurred serious adverse events that necessitated physical intervention of the on-road examiner (e.g., emergency brake, taking over the steering wheel).

Off-road testing battery at CARA. A detailed description of the visual and neuropsychological tests can be found in the supplementary material (e-methods).

Visual sensory information was gathered using the binocular acuity,(21) kinetic vision,(21) and Pelli-Robson contrast sensitivity tests.(22)

Motor symptoms were assessed using UPDRS III 'on'.(15) Participants were classified in terms of motor subtype as Postural Instability and Gait Disorder (PIGD), Tremor dominant (TD) or Indeterminate (IND) based on the relative predominance of tremor and gait/fall scores of the UPDRS II and UPDRS III, according to established clinical criteria.(23)

The cognitive battery was administered by board-certified neuropsychologists, who were blind to participants' results on the road test.

Executive functions and attention were evaluated using the 4-choice reaction time,(24) executive control,(25) incompatibility,(25) UFOV™,(26) and divided attention tests.(25)

Visuospatial functions were assessed using the ROCF(27) and visual scanning tests.(25)

Statistical analysis. Variables were screened for normality using the Kolmogorov-Smirnov test. All interval/ratio variables were not normally distributed. Chi-square, Fisher's Exact and Wilcoxon rank rum tests were used to explore differences between groups. Variables with $p < 0.10$ were subjected to multivariate stepwise logistic regression analysis. We used a forward selection procedure with a liberal entry criterion ($p < 0.15$) since p values < 0.05 may fail to identify important associations between variables.(28) The retain criterion remained stringent at $p < 0.05$. We verified for collinearity between independent variables by calculating variance inflation factors (VIF). The square root of VIF indicates how much of the standard error of the estimate is increased due to collinearity compared with a situation where the covariates are

uncorrelated. A VIF score of 10 or higher was considered to indicate substantial collinearity.(29) Spearman rank correlations (ρ) were calculated between off-road and on-road items. All statistical analyses were performed with SAS Enterprise 4.3 software. Two-tailed *P* values < 0.05 were considered significant.

RESULTS

All 104 participants had mild to moderate disease severity (Table 1). Nineteen were in H&Y stage 1, 41 in stage 2, and 44 in stage 3. The CARA referral group only scored worse on UPDRS III ($p = 0.02$). Eighteen participants (29%) recruited from the Clinic and another 18 (44%) recruited from CARA failed the road test ($X^2 = 2.58$, $p = 0.11$).

In all, 36 (35%) out of the 104 participants failed the road test (Table 2). Participants who failed were significantly older ($p < 0.001$), had longer driving history ($p = 0.008$), and drove less kilometers/year ($p = 0.007$) than those who passed. They were also more severely disabled as indicated by longer disease history ($p = 0.03$) and higher H&Y ($p = 0.0007$), CDR ($p < 0.0001$), and UPDRS II ($p = 0.0002$) scores. No differences were found in PD medication intake between the pass/fail groups.

Without exception, the fail group performed worse on all motor, visual sensory, executive and attention, and visuospatial tests (Table 2).The proportion of participants failing the on-road assessment was higher in the PIGD group compared to the TD group (46% vs 7%, post-hoc Fisher's Exact, $p < 0.0001$). The on-road failure rate of the IND group (33%) did not significantly differ from the other two groups.

The fail group scored worse on all driving items (Table 3) compared to the pass group ($p < 0.0001$).

All on-road items were entered in the multivariate logistic regression. Age and gender were forced into the model. Lateral position on the road at speed below 50 km/h, speed adaptations at speed above 50 km/h, and turning left showed to be most predictive of the on-road pass/fail decisions ($R^2 = 0.56$; Table 4). The VIF scores ranged between 2.13 and 2.91, indicating no substantial collinearity between predictors.

Moderate correlations were found between the off-road and on-road items. Lateral position on the road at speed below 50 km/h were associated with movement time of the 4-choice reaction time test ($\rho = -0.46$, $p < 0.0001$), UPDRS III ($\rho = -0.42$, $p < 0.0001$), and visual scanning ($\rho = -0.40$, $p < 0.0001$). CDR score ($\rho = -0.45$, $p < 0.0001$), UFOV total score ($\rho=-0.44$, $p < 0.0001$), and visual scanning ($\rho = -0.44$, $p < 0.0001$) correlated with speed adaptations at speed above 50 km/h. UFOV selective ($\rho = -0.46$, $p < 0.0001$), executive control ($\rho = -0.43$, $p < 0.0001$), and visual scanning ($\rho = -0.43$, $p < 0.0001$) correlated with left turning maneuvers.

All univariate variables with $p < 0.10$ (Table 2) were entered in the multivariate regression to predict the pass/fail decision. After adjustment for age and gender, visual scanning, UPDRS III scores, motor subtype, binocular visual acuity, incompatibility, and UFOV divided attention yielded the best model to determine outcome on the road test ($R^2 = 0.60$; Table 5). The odds of failing the road test was 24 times higher in the PIGD group than in the TD group. The VIF scores of the variables were low (range 1.09 – 2.40).

DISCUSSION

The novel contribution of our study to the field of driving in PD is the identification of critical impairments in specific driving skills that lead to failure on road testing: lateral position on the road at low speed, speed adaptations at high speed, and left turn maneuvers. Furthermore, we identified the underlying motor, visual, and cognitive impairments that predict failing the road test and performing poorly on these critical road skill items.

The critical impairments in road skills can be mapped onto existing theoretical frameworks on driving.(20) Lateral vehicle control at low speed is the most basic operational skill that is required for safe driving.(30) Several on-road(4) and driving simulator(31) experiments have found that drivers with PD exhibit problems keeping their car steady on the road. Vehicle control showed to correlate with motor functions (UPDRS III, motor reaction time) as expected since it involves basic operational skills.(20) Speed adaptation at higher speed is a tactical driving skill that requires drivers to constantly change their speed according to the posted speed limits, the speed of other cars, and the traffic density. In line with current knowledge,(32) impairments in speed adaptation showed to be associated with reduced cognitive abilities, especially in executive functions and attention. Turning left is considered among the most complex driving skills and the main cause for car crashes in older drivers.(33) The complexity of this driving skill is reflected by its association with higher order cognitive skills including visual scanning, working memory, cognitive inhibition, and selective attention.

On-road performance is determined by multidimensional factors involving both motor and non-motor aspects of PD. Independently of age and gender, (1) motor subtype, (2) motor symptom severity, (3) binocular acuity, (4) executive dysfunction (incompatibility), (5) divided attention, and (6) visual scanning provided the best predictive model of on-road failure in PD. The model explained 60% of the variance which is consistent with other studies.(34)

Previous studies demonstrated a relationship between impaired driving ability (on-road tests and car crashes) and motor components of PIGD (e.g., postural instability, functional reach or rapid pace walking).(3, 5, 35) The PIGD subtype is also associated with worse non-motor symptoms, including visual sensory, executive, and visuospatial dysfunction, which compromise instrumental daily-life activities.(36) Our results suggest that PIGD subtype is predictive of on-road driving performance, above and beyond motor severity scores.

Although UPDRS III 'off' scores proved to be better predictors of road testing,(10) we preferred to assess motor symptom severity in the 'on' medication phase because this status most likely reflects the condition in which persons are driving. Most studies reported primarily cognitive and visual predictors for road performance,(3, 5-8) mainly using dual task paradigms.(5-8) In the same cohorts,(5-8) motor dysfunction was an independent predictor of simulated driving when hazardous events were present that required fast reaction times.(8) In the present study, on-road tests were administered in a naturalistic traffic environment where potentially hazardous situations were constantly present, which may explain why motor impairment is associated with on-road performance.

Basic visual sensory dysfunction is often seen in mild to moderate PD.(37) In a cohort of 84 drivers with PD, significant associations were found between reduced far visual acuity and

number of at-fault safety errors on the road.(35) Our results confirm the associations between visual acuity and impaired driving, independent of age-related ocular pathologies.

We also observed differences in executive and attention between pass and fail groups, consistent with the findings of a recent evidence-based review.(10) Executive dysfunction is probably the most reported cognitive deficit in PD as part of global mild cognitive impairment, even in the early phases of the disease.(38) Executive dysfunction in PD encompasses deficits in planning and problem solving, decision making, set shifting, cognitive flexibility and interference, working memory, and selective attention,(38) all critical abilities for driving.

Finally, visual scanning emerged as the most important predictor of on-road failure and was significantly associated with the three most predictive on-road skill items. This finding is in agreement with a study that reported deteriorated visual scanning while driving in PD.(7) Visual scanning assesses the capability of actively exploring the visual field and is mediated by visual sensory and visual processing functions in addition to intact head and ocular movements in order to shift gaze, scan, and localize the target of interest among a clutter of distracters.(39)

A secondary but interesting finding study was lack of difference in pass/fail rates between participants referred for official driving evaluation at CARA (due to concerns raised by themselves, their family physicians, proxy, insurance company, or prosecution office)(11) and consecutive participants recruited from the Clinic who had no reported driving problems. The CARA referral group only showed worse UPDRS III scores. These findings suggest that the risk of poor road performance might go unrecognized in patients with lesser motor symptom severity from the community-dwelling PD population.

We used stringent eligibility criteria to mitigate the effect of age-related conditions on driving safety. Also, more than half of the patients were volunteers with no apparent driving problems before testing. This selection and participation bias may have led to an overrepresentation of safe drivers and may limit generalization of the findings to the population of PD drivers. Second, we could not determine a specific cut-off value for failing the on-road test, implicating that there is some subjectivity involved in failing drivers with PD. We made sure participants were tested when they felt optimal and we blinded the road assessor for the clinical and neuropsychological tests. Still, other factors (fatigue, personality characteristics, familiarity with the vehicle and road course) that were not measured may have contributed to the pass/fail decision. Finally, we chose to classify the motor subtypes of PD according to the most commonly used method of Jankovic et al.(23) This classification is easy to use in clinical practice, however, it is not confirmed by data-driven approaches.

Training programs for persons with mild to moderate PD may be useful to improve driving skills and prolong the preservation of mobility. Pilot studies on the efficacy of driving rehabilitation programs show that there is potential to improve driving skills in PD.(40) Our results provide a potential framework for future driving rehabilitation programs. For example, contextual training on the road or in a driving simulator in PD may focus on vehicle control, speed adaptations, and left turn maneuvers, whereas non-contextual rehabilitation may include physical therapy to address motor deficits, cognitive training to address visuospatial impairments, executive dysfunction and attention (e.g., speed of processing training), and compensation strategies to improve visual acuity (e.g., corrective lenses).

ACKNOWLEDGMENTS

We thank R. De Weze, B. De Winde, BS, T. Nijs, BS, M. Strypstein, MS, T. Vanleeuwe, MS, K. Verkammen, BS, and M. Van Weerst, MS, who provided administrative and technical assistance.

Conflict of Interest Disclosures: None reported.

Funding: This work was supported by the Department of Rehabilitation Sciences of KU Leuven and CARA, Belgian Road Safety Institute. Dr. Devos is a Postdoctoral Fellow and Dr. Vandenberghe is a Senior Clinical Investigator of the Research Foundation – Flanders. Dr. Devos received a travel stipend from the Belgian American Education Foundation (B.A.E.F.). Dr. Uc received funding from the National Institute of Health (R01 NS044930) and a Merit Review grant from Rehabilitation Research and Development Branch, the US Department of Veterans Affairs. The funding agencies were not involved in any part of the study.

AUTHOR'S ROLES:

Authors: Hannes Devos, Wim Vandenberghe, Alice Nieuwboer, Mark Tant, Willy De Weerdt, Jeffrey D. Dawson, Ergun Y. Uc

1. Research project: A. Conception, B. Organization, C. Execution

2. Statistical analysis: A. Design, B. Execution, C. Review and Critique

3. Manuscript preparation: A. Writing of the first draft, B. Review and Critique

Hannes Devos: 1. A, B, C

2. A, B

3. A

Wim Vandenberghe:	1. B, C
	2. C
	3. B
Mark Tant	1. B, C
	2. C
	3. B
Abiodun Akinwuntan	1. A
	2. C
	3. B
Willy De Weerdt	1. A, B
	2. C
	3. B
Alice Nieuwboer	1. A, B
	2. C
	3. B
Ergun Y Uc	1. A
	2. A, C
	3. B

FULL FINANCIAL DISCLOSURE OF PRECEDING 12 MONTHS

Hannes Devos

Stock ownership in medically-related fields	None
Consultancies	None
Advisory boards	None
Partnership	None
Honoraria	None
Grants	Postdoctoral fellowship Research Foundation – Flanders; Travel grant Research Foundation – Flanders; Belgian American Educational Foundation Fellowship

Wim Vandenberghe

Stock ownership in medically-related fields	None
Consultancies	None
Advisory boards	None
Partnership	None
Honoraria	None
Grants	None

Mark Tant

Stock ownership in medically-related fields	None

Consultancies	None
Advisory boards	None
Partnership	None
Honoraria	None
Grants	None

Abiodun E Akinwuntan

Stock ownership in medically-related fields	None
Consultancies	None
Advisory boards	None
Partnership	None
Honoraria	None
Grants	None

Willy De Weerdt

Stock ownership in medically-related fields	None
Consultancies	None
Advisory boards	None
Partnership	None
Honoraria	None
Grants	None

Alice Nieuwboer

Stock ownership in medically-related fields	None
Consultancies	None
Advisory boards	None
Partnership	None
Honoraria	None
Grants	None

Ergun Y Uc

Stock ownership in medically-related fields	None
Consultancies	None
Advisory boards	None
Partnership	None
Honoraria	None
Grants	VA Merit Review B6261R, VA Merit Review RX000170-01

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Table 1 Characteristics of the total PD group and two recruitment groups

Variables	All (n = 104)	Clinic (n = 63)	CARA (n = 41)	p value
Demographics	*n (%)*	*n (%)*	*n (%)*	χ^2
Gender, male	87 (84)	54 (86)	33 (80)	0.48
	median (Q1 – Q3)	*median (Q1 – Q3)*	*median (Q1 – Q3)*	*Wilcoxon*
Age, y	66 (59 – 73)	66 (60 – 73)	64 (53 – 73)	0.54
Education, y	13 (11 – 16)	13 (11 – 15)	13 (11 – 16)	0.80
Driving variables	*n (%)*	*n (%)*	*n (%)*	*Fisher*
Self-appraisal of driving fitness (NR/R/U)	76 (73)/28 (27)/0 (0)	48 (76)/15 (24)/0 (0)	28 (68)/13 (30)/0 (0)	0.37
	median (Q1 – Q3)	*median (Q1 – Q3)*	*median (Q1 – Q3)*	*Wilcoxon*
Driving history, y	42 (36 – 49)	42 (38 – 50)	41 (33 – 48)	0.27
Driving exposure, 10^3 km	10 (5 – 15)	10 (5 – 15)	10 (5 – 12.50)	0.76
Traffic tickets in last five years, n	0 (0 – 1)	0 (0 – 1)	0 (0 – 1)	0.35
Crashes in last five years, n	0 (0 – 0)	0 (0 – 0)	0 (0 – 1)	0.06
Disease characteristics	*median (Q1 – Q3)*	*median (Q1 – Q3)*	*median (Q1 – Q3)*	*Wilcoxon*
Disease duration, y	6 (4 – 9)	6 (3 – 10)	6 (4 – 7)	0.82
Hoehn and Yahr 'on', /5 (↓)	2 (2 – 3)	2 (2 – 3)	2 (2 – 3)	0.29
Epworth Sleepiness Scale,[a] /27 (↓)	5 (3 – 8)	5 (4 – 9)	5 (3 – 6.5)	0.32
Clinical Dementia Rating,[a] /3 (↓)	0 (0 – 0.25)	0 (0 – 0.5)	0 (0 – 0)	0.56
UPDRS II,[a] /48 (↓)	9 (5 – 12.50)	9 (4 – 12)	11 (7 – 13)	0.15
UPDRS III,[a] /108 (↓)	23 (16 – 33)	21 (16 – 29)	28 (18 – 37)	0.02
L-dopa equivalent dosage, mg/day	463 (275 – 668)	450 (255 – 610)	490 (300 – 775)	0.51
	n (%)	*n (%)*	*n (%)*	*Fisher*
Use of amantadine, yes	10 (10)	7 (11)	3 (7)	0.73
Use of anticholinergics, yes	8 (8)	6 (9)	2 (5)	0.47
	n (%)	*n (%)*	*n (%)*	χ^2
Use of MAO-B inhibitors, yes	36 (35)	18 (29)	18(44)	0.11
Motor subtype (PIGD/TD/IND)[a]	59 (59) / 29 (29) /12 (12)	33 (52) / 23 (37) / 7 (11)	26 (70) / 6 (16) / 5 (14)	0.73

[a] Missing data of four persons.

Abbreviations: CARA = Center for Evaluation of Fitness to Drive and Car Adaptations; IND, Indeterminate; NR = No Restrictions on driver's license needed; PIGD, Postural Instability and Gait Disorder; PD = Parkinson's disease; R = Restrictions on driver's license needed; ROCF = Rey-Osterrieth Complex Figure; TD = Tremor Dominant; U = subject considers himself Unfit to drive; UFOV, Useful Field Of View; UPDRS II, Unified Parkinson's Disease Rating Scale Activities of the Daily Living; UPDRS III Unified Parkinson's Disease Rating Scale motor section.

Upward arrows indicate better performance with higher scores; downward arrows indicate worse performance with higher scores.

Table 2 Differences in demographics, disease characteristics and off-road performance between pass and fail groups

Off-road variables	Pass (n = 68)	Fail (n = 36)	p value
Demographic and disease characteristics	*n (%)*	*n (%)*	χ^2
Gender, male	57 (84)	30 (83)	0.95
	median (Q1 – Q3)	*median (Q1 – Q3)*	*Wilcoxon*
Age, y	63 (53 – 69)	72 (65 – 75)	< 0.0001
Education, y	14 (11 – 16)	12 (11 – 15)	0.39
Driving history, y	41 (32 – 48)	46 (41 – 53)	0.008
Annual mileage, 10^3 km	10 (7 – 19)	8 (5 – 10)	0.007
Traffic tickets in last five years, n	0 (0 – 1)	0 (0 – 0)	0.14
Crashes in last five years, n	0 (0 – 0)	0 (0 – 1)	0.12
Disease duration, y	5 (3 – 9)	6 (5 – 10)	0.03
Hoehn and Yahr 'on', /5 (↓)	2 (2 – 3)	3 (2 – 3)	0.0007
Epworth Sleepiness Scale,[a] /27 (↓)	5 (4 – 8)	5 (3 – 8)	0.84
Clinical Dementia Rating,[a] /3 (↓)	0 (0 – 0)	0.50 (0 – 0.50)	< 0.0001
UPDRS II,[a] /48 (↓)	7 (4 – 11)	12 (8 – 14)	0.0002
L-dopa equivalent dosage, mg/day	463 (290 – 763)	433 (268 – 600)	0.54
	n (%)	*n (%)*	*Fisher*
Use of amantadine, yes	6 (9)	4 (11)	0.74
Use of anticholinergics, yes	6 (9)	2 (6)	0.71
	n (%)	*n (%)*	χ^2
Use of MAO-B inhibitors, yes	24 (35)	12 (33)	0.84
Motor tests	*n (%)*	*n (%)*	*Fisher*
Motor subtype (PIGD/TD/IND)[a]	32 (54) / 27 (93) / 8 (67)	27 (46) / 2 (7) / 4 (33)	0.001
	median (Q1 – Q3)	*median (Q1 – Q3)*	*Wilcoxon*
UPDRS III,[a] /108 (↓)	20 (13 – 25)	35 (26 – 43)	< 0.0001
4-choice motor reaction time,[a] ms (↓)	274 (226 – 338)	390 (304 – 427)	< 0.0001
Visual tests			
Binocular visual acuity, /10 (↑)	10 (8 – 10)	8 (8 – 8)	< 0.0001
Kinetic vision,[a] /9 (↑)	7 (6 – 8)	6 (5 – 7)	0.004
Contrast sensitivity, /2.25 (↑)	1.80 (1.65 – 1.95)	1.65 (1.50 – 1.65)	< 0.0001
Executive function and attention tests			
4-choice decision time,[a] ms (↓)	377.50 (345 – 425)	416 (383 – 467)	0.001
Executive control, omissions (↓)	1 (0 – 2)	4.50 (2 – 8)	< 0.0001
Incompatibility, errors (↓)	1 (1 – 2)	2.50 (0 – 7)	0.04
UFOV total score, % (↓)	7.50 (0 – 12.50)	27.50 (7.50 – 40)	< 0.0001
UFOV speed of processing, % (↓)	0 (0 – 0)	0 (0 – 0)	0.01
UFOV divided attention, % (↓)	0 (0 – 0)	5 (0 – 11.50)	< 0.0001
UFOV selective attention, % (↓)	7.50 (0 – 12.50)	17.50 (7.50 – 25)	0.0007
Divided attention, omissions (↓)	1.50 (0 – 3)	3.50 (1 – 5)	0.0006
Visuospatial tests			
ROCF, /36 (↑)	35.50 (34 – 36)	34 (31 – 35)	0.0003
Visual scanning, ms (↓)	3343 (2795 – 4105)	5001 (4027 – 5736)	< 0.0001

[a] Missing data of four persons.

Abbreviations: IND, Indeterminate; PIGD, Postural Instability and Gait Disorder; ROCF = Rey-Osterrieth Complex Figure; TD = Tremor Dominant; UFOV, Useful Field Of View; UPDRS II, Unified Parkinson's Disease Rating Scale Activities of the Daily Living; UPDRS III Unified Parkinson's Disease Rating Scale motor section.

Upward arrows (↑), better performance with higher scores; downward arrows (↓), worse performance with higher scores.

Table 3 On-road driving performance in the pass and fail groups

Item	Variable	Score range	Pass (n = 68) *median (Q1 – Q3)*	Fail (n = 36) *median (Q1 – Q3)*	p value Wilcoxon
	Total TRIP score	49 – 196	196 (185 – 196)	146 (123 – 167)	< 0.0001
	Operational cluster				
I	Lateral position on the road at speed below 50 km/h	2 – 8	8 (8 – 8)	6 (6 – 8)	< 0.0001
II	Lateral position on the road at speed above 50 km/h	2 – 8	8 (8 – 8)	6 (4 – 8)	< 0.0001
III	Mechanical operations	3 – 12	12 (12 – 12)	11 (9 – 12)	< 0.0001
	Tactical cluster				
IV	Speed adaptations at speed below 50 km/h	2 – 8	8 (8 – 8)	6 (6 – 8)	< 0.0001
V	Speed adaptations at speed above 50 km/h	2 – 8	8 (8 – 8)	5 (4 – 6)	< 0.0001
VI	Gap distance at speed below 50 km/h	2 – 8	8 (8 – 8)	8 (6 – 8)	< 0.0001
VII	Gap distance at speed above 50 km/h	2 – 8	8 (8 – 8)	6 (4 – 8)	< 0.0001
VIII	Lane position change	5 – 20	20 (20 – 20)	16 (14 – 20)	< 0.0001
	Visuo-integrative cluster				
IX	Anticipation and perception of signs and traffic lights	4 – 16	16 (16 – 16)	11 (8 – 16)	< 0.0001
X	Visual behavior and communication	8 – 32	32 (28 – 32)	23 (16 – 25)	< 0.0001
	Mixed cluster				
XI	Understanding, insight and quality of traffic participation	2 – 8	8 (8 – 8)	6 (4 – 6)	< 0.0001
XII	Turning left	9 – 36	36 (34 – 36)	26 (23 – 29)	< 0.0001
XIII	Joining the traffic stream	6 – 24	24 (24 – 24)	18 (15 – 22)	< 0.0001

Abbreviations: TRIP, Test Ride for Investigating Practical fitness to drive; Wilcoxon, Wilcoxon rank sum test

Table 4 Multivariate logistic regression of the road items to determine on-road driving decisions

Variable	Unit increase	Odds Ratio	95% Confidence Interval		P value
			Lower CI	Higher CI	
Age[a]	1 year	1.211	1.033	1.419	0.02
Gender[a]	m vs f	0.146	0.009	2.427	0.18
Lateral positioning on the road at speed below 50 km/h	1 point	0.235	0.082	0.675	0.007
Speed adaptations at speed above 50 km/h	1 point	0.257	0.100	0.659	0.005
Turning left	1 point	0.762	0.608	0.955	0.02

[a] Age and gender were forced in the model.

Abbreviations: CI, Confidence Interval

Table 5 Multivariate logistic regression of the off-road battery to determine on-road decisions

Variable	Unit increase	Odds Ratio	95% CI		p value
Age[a]	1 year	1.168	1.034	1.320	0.01
Gender [a]	m vs f	0.390	0.028	5.397	0.48
Visual scanning	1 millisecond	1.003	1.001	1.005	0.002
UPDRS III 'ON'	1 point	1.168	1.053	1.296	0.003
Motor subtype					
	TD vs IND	0.113	0.001	8.601	0.32
	PIGD vs IND	1.256	0.889	1.364	0.68
	PIGD vs TD	24.483	2.334	54.895	0.0009
Binocular acuity	1 point	0.319	0.133	0.764	0.01
UFOV divided attention	2.5%	0.758	0.582	0.987	0.04
Incompatibility	1 error	0.841	0.714	0.991	0.04

[a] Age and gender were forced in the model.

Abbreviations: CI, Confidence Interval; UPDRS III, Unified Parkinson's Disease Rating Scale motor section; UFOV, Useful Field Of View; TD, tremor-dominant; IND, indeterminate; PIGD, Postural Imbalance and Gait Disorder.