Predictors of fitness to drive in people with Parkinson disease

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ABSTRACT

Objective: To develop an efficient clinical screening battery to accurately predict the fitness to drive in people with Parkinson disease (PD).

Methods: This prospective study included 80 participants: 40 patients with PD and 40 healthy age- and sex-matched control subjects. All participants were assessed using a driving simulator, a driving history survey, and the Clinical Dementia Rating. The patients with PD also underwent a clinical test battery and an evaluation of fitness to drive performed by an official center, which included visual, cognitive, and on-road tests. A two-class decision from this driving assessment center was the main outcome measure.

Results: A screening battery assessing four clinical variables (disease duration, contrast sensitivity, Clinical Dementia Rating, and motor part of the Unified Parkinson's Disease Rating Scale) provided the best model (R^2 = 0.52) to predict the fitness to drive and correctly classified 36 (90%) of the patients with PD as pass or fail (sensitivity = 91%, specificity = 90%). The Test Ride for Investigating Practical fitness to drive (TRIP) driving simulator score discriminated significantly between drivers with PD and their healthy peers (p = 0.0008). When the TRIP driving simulator score was added to the clinical model, the total explained variance increased (R^2 = 0.60) and correctly classified 39 (97.5%) of drivers with PD into the pass/fail category (sensitivity = 91%, specificity = 100%).

Conclusions: A short clinical screening battery that measures disease duration, contrast sensitivity, cognitive and motor functions can predict fitness to drive in people with Parkinson disease with a high degree of accuracy. ***Neurology*® 2007;69:1434–1441**

GLOSSARY

ADL = activities of daily living; **CDR** = Clinical Dementia Rating; **CS** = contrast sensitivity; **DBS** = deep brain stimulator; **ESS** = Epworth Sleepiness Scale; **IQR** = interquartile range (Q1–Q3); **NA** = not applicable; **PD** = Parkinson disease; $\mathbf{r_b}$ = biserial correlation coefficient; $\mathbf{r_{rb}}$ = rank biserial correlation coefficient; $\mathbf{r_s}$ = Spearman rank correlation coefficient; **TRIP** = Test Ride for Investigating Practical fitness to drive; **UFOV** = useful field of view; **UPDRS II** = Unified Parkinson's Disease Rating Scale, activities of daily living; **UPDRS III** = Unified Parkinson's Disease Rating Scale, motor scale; **w** = Wilcoxon rank sum test.

Patients with Parkinson disease (PD) have progressive motor,[1] cognitive,[1,2] visual processing,[3] and emotional[4] deficits that may affect safe driving behavior.[5-15]

The legislative procedures to screen drivers with PD vary greatly across Europe and the United States.[16-18] In some countries, driver's license renewal is merely an administrative procedure or an assessment of visual function.[16,17] In other countries, the procedures toward license renewal are based on face validity rather than on scientific ascertained evidence.[19,20]

Physicians' appraisal of driving proficiency is often inconsistent and only moderately predictive of driving performance as assessed by driving experts.[5] Only three studies have investigated the ability of a clinical screening battery to predict the fitness to drive in patients with PD.[5-7] A combination of visual processing, L-dopa dose, and age explained

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Funded by a grant from the Nationale Vereniging voor Steun aan Gehandicapten and DVV insurances of Belgium. W.V. is a Senior Clinical Investigator of the Fund for Scientific Research–Flanders.

Disclosure: The authors report no conflicts of interest.

Table 1 Characteristics of participant groups

Variable	PD patients (n = 40)	Controls (n = 40)	Statistic	*p* Value
Age, y				
Mean ± SD (range)	61.6 ± 9.4 (44–75)	62.8 ± 7.6 (51–79)	t = 0.61	0.54
Driving experience, y				
Mean ± SD (range)	39.2 ± 9.8 (10–58)	40.8 ± 7.1 (30–56)	t = 0.83	0.41
Distance driven annually (10^3 km)				
Median (IQR)	10 (5.5–16)	14 (9.9–17.5)	w = 1455	0.12
Clinical Dementia Rating (↓)				
Median (IQR)	0 (0–0.5)	0 (0–0)	w = 1780	0.02
Disease duration, y				
Mean ± SD (range)	6.7 ± 4.0 (5–20)	NA		
L-Dopa equivalent dosage (mg/day)				
Mean ± SD (range)	509 ± 238 (0–1,247)	NA		
Hoehn and Yahr (on)				
Median (IQR)	2 (1.5–3)	NA		

Downward arrow means lower score better.
t = *t* test (unpaired); w = Wilcoxon rank sum test; IQR = interquartile range (Q1–Q3); NA = not applicable.

67% of the variation in faults in a driving test.[5] Another model containing dot cancellation errors, delayed story recall, information processing, as well as hand tapping accounted for 44% of the variance in on-road perfomance.[6] Time since diagnosis, Purdue Pegboard test, contrast sensitivity, and the verbal version of the Symbol Digit Modalities Test correctly classified 90% of the drivers with PD into a pass/fail category derived from an on-road test.[7] None of the aforementioned studies specified how to use their respective models in clinical practice.[5-7]

The main aim was to develop a short clinical battery to assist physicians to identify safe and unsafe drivers with PD. The second aim was to determine the additional value of a driving simulator evaluation in the prediction of fitness to drive.

METHODS

Subjects. Diagnosis of PD was based on the UK Brain Bank Diagnostic Criteria.[21] Patients with PD were included if they signed the informed consent form, had a valid driver's license, were still regularly driving, were in Hoehn and Yahr (on) stage 1 to 3, scored equal to or less than 1 on the Clinical Dementia Rating (CDR),[22] and had a minimum binocular acuity score of 10/20 on the Snellen acuity chart.[23] Exclusion criteria were deep brain stimulator (DBS) implants and unpredictable motor fluctuations.

A total of 53 patients with PD were invited to participate. Thirty-four patients (28 men, 6 women) recruited through the Movement Disorders Unit of the University Hospital Gasthuisberg and six subjects (5 men, 1 woman) through the Flemish PD Society consented. Forty age- and sex-matched controls (31 men, 9 women) without neurologic impairments volunteered after attending lectures about the study. Participants' characteristics are summarized in table 1. Twenty-nine patients with PD and 36 controls had no cognitive deterioration (CDR = 0). Eleven patients with PD and 3 controls showed very mild cognitive decline (CDR = 0.5). None of the participants presented with mild cognitive impairment (CDR = 1). All patients with PD were assessed in the on-phase at standardized test times after intake of medication to minimize the effect of predictable wearing-off on test results. The assessments were temporarily interrupted when patients were at end-of-dose and were resumed approximately half an hour after medication intake when they were again in an optimal state.

Testing occurred in random sequence at two different locations (University Hospital, Leuven, and CARA, Brussels) on two separate days. The motor part of the Unified Parkinson's Disease Rating Scale[24] (UPDRS III) was rated immediately before assessment by the same observer (H.D.) to assure a comparable motor state on both examination dates. Median UPDRS III scores were not significantly different on both days (Wilcoxon signed rank test = 80.5; $p = 0.23$).

The study was approved by the ethical committee of the University Hospitals Leuven.

Clinical assessment. L-Dopa equivalent dose intake[25] (mg/day) and Hoehn and Yahr (on) stage were registered (table 1). Driving habits, self-reported traffic penalties, and accidents over the past 5 years were documented. Drivers with PD were asked to self-appraise their fitness to drive as "fit to drive without restrictions," "fit to drive with restrictions," and "unfit to drive" (see below).

The validated Epworth Sleepiness Scale (ESS) comprises eight different situations in which subjects rate how likely they are to fall asleep. Scores on each item vary

from 0 to 3 (no chance–high chance), giving a total range score from 0 to 24.[26,27]

Contrast sensitivity (CS) was determined using the Pelli-Robson chart. Subjects were asked to read eight lines of triplets with decreasing contrast. Each triplet was scored as 0.15 log units.[28]

Patients were asked to copy the complex figure of Rey and were scored on accuracy, correctness, and organization with a maximum score of 36.[29]

The CDR evaluates six domains of cognitive and functional performance on a 5-point ordinal scale. Zero indicates no dementia; 0.5, very mild; 1, mild; 2, moderate; and 3, severe dementia.[22]

The UPDRS II assesses activities of daily living (ADL) with a total range from 0 to 52.[24] Motor symptoms were assessed using the UPDRS III, with a total range from 0 to 108.[24]

CARA assessment. In Belgium, the Center for Fitness to Drive Evaluation and Car Adaptations (CARA) of the Belgian Road Safety Institute is responsible for the determination of fitness to drive in all people with functional disabilities. All patients with PD underwent an official driving evaluation that lasted on average 3 to 4 hours. A detailed description of this standardized assessment can be found elsewhere.[19] The CARA decision regarding fitness to drive is taken by a team consisting of a physician, a neuropsychologist, and an expert in practical fitness to drive. People categorized as fit to drive without restrictions can resume driving a car with manual or automatic transmission, but need to be re-evaluated after 1 to 5 years. People judged fit to drive with restrictions can continue to drive, but during daylight only, with a speed limit, in a radius of x km near their home, or not on highways. Those judged unfit to drive are informed to hand in their driving license to the authorities. For the purpose of this study, the original three-class decision of CARA was dichotomized as pass (fit to drive without restrictions) and fail (fit to drive with restrictions and unfit to drive).

The tests for binocular visual acuity and kinetic vision were performed on Ergovision equipment.[23] Visual field was assessed using the Humphrey Field Analyzer/HFA II-i.

The neuropsychological tests comprised the figure of Rey,[29] reaction times,[30] useful field of view[31,32] (UFOV), executive control,[33] visual scanning,[33] divided attention,[33] and incompatibility.[33]

On-road driving performance was evaluated by an expert in assessing practical fitness to drive in neurologically impaired persons. After road test completion, subjects' performance was scored on the Test Ride for Investigating Practical fitness to drive (TRIP) checklist.[34] It contains 13 items of driving performance and is made up of 49 subitems that are each scored using clearly predefined criteria on a four-point scale of poor = 1, fair = 2, sufficient = 3, and good = 4, giving a total score range from 49 to 196. The reliability and validity of the road test were established earlier.[35,36]

Driving simulator assessment. To determine the additional value of a driving simulator assessment in the prediction of fitness to drive in patients with PD, we first investigated the discriminant ability of such a simulator. Therefore, all 40 patients with PD and 40 healthy, age- and sex-matched volunteers were evaluated in a driving simulator, a stationary full-sized Ford Fiesta 1.8 car with automatic gear transmission and all its original mechanical parts. It was powered on STISIM Drive system, model 300, Version 1.03.05 manufactured by Systems Technology Inc., Hawthorne, CA. The driving scenario was projected onto a flat screen (approximately 2.30 m by 1.70 m) with a visual angle of 45°. Participants first drove a 6 km road course to get familiarized with the driving simulator. Afterwards, they were evaluated on a 15 km course, including frequently occurring traffic situations. Participants' performance was scored on a modified TRIP checklist,[34] with a total range score from 30 to 120. Computerized performance measures such as number of traffic offenses and accidents were also obtained. Traffic offenses included speeding (>8 km/hour above the speed limit), number of traffic light faults, and number of wrong turns. Accidents consisted of on-road accidents, off-road accidents, traffic cone hits, and pedestrian hits. Finally, divided attention was documented as well. Subjects had to respond by pressing the horn, left or right indicator as soon as one of these symbols was presented in the periphery of the screen. If the subject did not respond within 5 seconds, the symbol was recorded as missed. Twenty-eight symbols were presented in total. Mean reaction times, omissions, and errors were recorded.

Statistical analysis. H. Devos conducted the biostatistical analysis, under supervision of Prof. Dr. W. De Weerdt and Prof. Dr. A. Nieuwboer.

The percentage of agreement between self-appraisal of fitness to drive and the three-class CARA decision was investigated using the weighted kappa (κ) statistic. An agreement of 0.60 and higher was considered acceptable.[37]

Unpaired *t* tests were used to test the significance of differences of performance on the pre-driving assessment between patients who passed the CARA tests and those who failed, when ratio variables were normally distributed. Wilcoxon rank sum test was used for ordinal variables and ratio variables that were not normally distributed. χ^2 Statistics were used for nominal data. Bonferroni correction for multiple comparisons was applied for all variables of the pre-driving assessment, except for the descriptive measures. *p* Values less than 0.008 (0.05/6) were considered significant for the clinical tests. The significance level for the driving simulator evaluation was set at $p < 0.007$ (0.05/7).

Relationships between predictor variables and the two categories of the outcome variable (pass and fail) were investigated using biserial, rank biserial, and Spearman rank correlation coefficients.

Logistic regression analysis was conducted to predict the pass/fail decision. Variables were only entered into the regression model if they were clinically relevant, had significant correlation with pass/fail decision, differed significantly between categories of driving decision, and had high univariate predictive accuracy. Significance testing of the predictor variables was based on Wald χ^2 statistics.

To obtain a clinically applicable equation for predicting the pass/fail classification, a discriminant function analysis was performed including the tests used in the logistic regression model.

The Wilcoxon rank sum test was used to test the significance of the difference between the driving simulator scores of patients with PD and those of healthy individuals.

All analyses were performed with the statistical program SAS 9.1 and SAS Enterprise Guide 3.0.[38]

RESULTS

The official CARA assessment was performed on all drivers with PD. It involved tests

for visual function, cognitive performance, and an on-road test. Twenty-nine patients (72.5%) were judged as fit to drive without restrictions, 10 (25%) as fit to drive with restrictions, and 1 (2.5%) was classified as unfit to drive.

Eight patients (20%) misjudged their own driving performance. Three rated themselves as fit to drive with restrictions while the assessors categorized them as fit to drive without restrictions. Five considered themselves as fit to drive without restrictions, of which four were actually judged as fit to drive with restrictions and one as unfit to drive. The weighted kappa between the patient's self-perception of fitness to drive and the three-class decision of CARA was 0.44.

Results of the predictor variables are shown in table 2. From the clinical assessment, disease duration, patients' self-appraisal of fitness to drive, CS, CDR, and UPDRS III correlated significantly with the dichotomous outcome variable and discriminated between drivers with PD who passed and failed the official driving assessment. Since patient's self-appraisal did not provide additional predictive value, only disease duration, CS, CDR, and UPDRS III were retained in the logistic regression model. A combination of these four variables yielded a model accounting for 52% of the variance.

Discriminant function analysis to predict the pass/fail classification of fitness to drive correctly classified 36 (90%) of the subjects with PD using the equations below:

Pass = (CS*139.97)
+ (CDR*1.49) – (UPDRS III*0.18)
– (disease duration*1.30) – 125.42

Fail = (CS*123.02)
+ (CDR*5.66) – (UPDRS III*0.02)
– (disease duration*0.97) – 101.93

If the result of subtracting the fail score from the pass score was positive (negative), the subject was predicted to pass (fail).

To make this more practical, the two prediction equations were condensed into one:

(CS*16.95) – (CDR*4.17) – (UPDRS III*0.16)
– (disease duration*0.33) – 23.49

If the outcome on the prediction equation was positive, the subject was predicted to pass. If the result was negative, the subject was predicted to fail.

Twenty-six of the 29 subjects who passed the CARA examination were correctly predicted as pass by our prediction model, which corresponds to a specificity of 90%. The sensitivity, defined as the number of subjects correctly predicted to fail, was 91% (table 3).

Patients with PD scored significantly worse than controls on the driving simulator evaluation. TRIP score, number of traffic offenses, total number of traffic offenses and accidents, and reaction times on the divided attention task were significantly higher among the drivers with PD (table 4).

From the driving simulator evaluation, only TRIP driving simulator score showed a significant correlation and differentiated between pass and fail drivers (table 2). When the TRIP driving simulator score was added to the clinical screening battery, the total explained variance increased to 60%. Discriminant function analysis correctly classified 39 (97.5%) of the subjects with a specificity of 100% and a sensitivity of 91% with the following equations:

Pass = (TRIP driving simulator score*2.25)
+ (CS*103.85) + (CDR*14.79)
– (UPDRS III*0.07)
– (disease duration*1.04) – 222.59

Fail = (TRIP driving simulator score*1.96)
+ (CS*91.47) + (CDR*17.28)
+ (UPDRS III*0.08)
– (disease duration*0.75) – 176.05

The condensed prediction equation was as follows:

(TRIP driving simulator score*0.29)
+ (CS*12.38) – (CDR*2.49)
– (UPDRS III*0.15)
– (disease duration*0.29) – 46.54

DISCUSSION The majority of the drivers with PD included in the present study were found to be safe drivers. This may implicate that a large proportion of drivers with PD self-regulate their driving habits. However, patients with diminished driving skills may be reluctant to participate in studies investigating their fitness to drive. This may have affected the high proportion of safe drivers. It is however important to note that prior to testing, all 40 patients with PD were driving with no limitations to their driver's license. After

Table 2 Comparison of pass and fail drivers with Parkinson disease and correlation with pass/fail decision

Pre-driving assessment variables	Pass (n = 29)	Fail (n = 11)	Statistic	*p* Value	Correlation pass/fail decision	*p* Value
Clinical assessment						
Descriptive measures					r_b	
Age, y, mean ± SD	60 ± 10.14	66 ± 5.50	t = −2.36	0.02*	0.28	0.08
Driving experience, y, mean ± SD	38.07 ± 8.85	42.18 ± 11.95	t = −1.19	0.24	−0.24	0.13
Distance driven annually (10^3 km), median (IQR)	10 (7–17)	5 (3–10)	w = 154	0.04*	0.19	0.24
Traffic penalties, median (IQR) (↓)	0 (0–1)	0 (0–0)	w = 210.5	0.57	−0.09	0.58
Accidents, median (IQR) (↓)	0 (0–0)	0 (0–0)	w = 209	0.29	−0.18	0.28
Disease duration, y, mean ± SD	5.88 ± 3.22	8.95 ± 4.97	t = −2.31	0.03*	0.35	0.03*
L-Dopa equivalent dosage (mg/day), mean ± SD	536.58 ± 244.79	436.17 ± 210.89	t = 0.34	0.16	−0.16	0.34
					r_{rb}	
Sex, n, M/F	23/6	10/1	X = 0.72	0.39	−0.14	0.4
					r_s	
Hoehn and Yahr (on), median (IQR) (↓)	2 (1–3)	3 (2.5–3)	w = 249.5	0.45	0.13	0.44
Self-appraisal of fitness to drive, median (IQR) (↓)	1 (1–1)	1 (1–2)	w = 296	0.006*	0.47	0.002*
Clinical tests						
Sleeping Questionnaire						
ESS, mean ± SD (↓)	5.86 ± 4.16	7.55 ± 4.87	t = −1.09	0.28	0.18	0.27
Visual tests						
CS, median (IQR) (↑)	1.95 (1.8–1.95)	1.65 (1.65–1.95)	w = 146.5	0.007†	−0.44	0.004†
Cognitive tests						
Figure of Rey, median (IQR) (↑)	36 (35–36)	34 (33–35.5)	w = 164	0.06	−0.31	0.05
CDR, median (IQR) (↓)	0 (0–0)	0.5 (0–0.5)	w = 305	0.004†	0.5	0.001†
ADL activities						
UPDRS II (on), mean ± SD (↓)	7.17 ± 4.13	12 ± 5.39	t = −3.03	<0.0001†	0.41	0.009
Motor tests						
UPDRS III (on), mean ± SD (↓)	16.79 ± 8.48	29.82 ± 11.56	t = −3.91	0.004†	0.5	0.001†
Driving simulator evaluation						
TRIP driving simulator score, median (IQR) (↑)	116 (112–119)	100 (88–107)	w = 86	0.0001‡	−0.68	<0.0001‡
Traffic offenses, median (IQR) (↓)	1 (0–2)	3 (2–4)	w = 314	0.01	0.46	0.003‡
Accidents, median (IQR) (↓)	0 (0–1)	1 (0–3)	w = 272.5	0.15	0.39	0.01
Total number of traffic offences and accidents, median (IQR) (↓)	1 (0–2)	1 (1–2)	w = 296.5	0.02	0.23	0.15
Divided attention					r_b	
Mean reaction time, median (IQR) (↓)	2.52 (1.88–3.21)	2.92 (2.21–4.58)	w = 267.5	0.22	0.44	0.005‡
Omissions, median (IQR) (↓)	6 (2–10)	11 (6–27)	w = 296	0.04	−0.38	0.02
Errors, median (IQR) (↓)	2 (2–4)	1 (0–2)	w = 148	0.02	0.28	0.08

Upward arrow means higher score better; downward arrow means lower score better.
*$p < 0.05$ was considered significant for the descriptive measures.
†$p < 0.008$ was considered significant after Bonferroni correction of the clinical tests.
‡$p < 0.007$ was considered significant after Bonferroni correction of the driving simulator evaluation.
r_b = biserial correlation coefficient; t = *t* test for independent samples; IQR = interquartile range (Q1–Q3); w = Wilcoxon rank sum test; X = χ^2 test; r_{rb} = rank biserial correlation coefficient; r_s = Spearman rank correlation coefficient; ESS = Epworth Sleepiness Scale; CS = contrast sensitivity; CDR = Clinical Dementia Rating; ADL = activities of daily living; UPDRS II = Unified Parkinson's Disease Rating Scale, activities of daily living; UPDRS III = Unified Parkinson's Disease Rating Scale, motor scale; TRIP = Test Ride for Investigating Practical fitness to drive.

Table 3 Classification of drivers with Parkinson disease based on four clinical variables

		Clinical assessment outcome		
		Pass, n (%)	Fail, n (%)	Total, n (%)
CARA decision	Pass, n (%)	26 (65)	3 (7.5)	29 (72.5)
	Fail, n (%)	1 (2.5)	10 (25)	11 (27.5)

assessment, only 29 (72.5%) patients with PD were found to be fit to drive without restrictions.

There was a high disagreement between the patient's self-perception of fitness to drive and the three-class CARA decision. Five of eight patients who misjudged themselves did not restrict their driving behavior and drove unaware of their diminished driving skills.

Self-reported traffic penalties and accidents did not differ between drivers with PD who passed and those who failed. This has important repercussions because insurance companies and neurologists tend to withhold patients' drivers licenses after (several) accidents or repeated reprimands by the police.

These three findings emphasize the need for adequate assessment. People judged as pass by the pre-driving screening battery should be allowed to resume driving without any further restrictions, while people categorized as fail should be referred to a specialized center for further evaluation of fitness to drive.

A combination of disease duration, contrast sensitivity, Clinical Dementia Rating, and UPDRS III constituted a logistic regression model with the highest predictive accuracy. The moderate variance explained by this model is consistent with other studies.[5,6] Other plausible factors not measured in this study, such as personality, vehicle familiarization, risk assessment, as well as other unknown factors, may have influenced patient performance.

Using discriminant function analysis, we were able to derive a formula that predicted the official fitness-to-drive decision with 90% accuracy. Ideally, we would want a model that correctly predicts all patients who fail in the official assessment, but a sensitivity of 91% is already encouraging. The fact that the four tests of this model are objective, standardized, easy to administer, and can be applied within the consultation routine of the physician, gives high clinical relevance to the model.

When the TRIP driving simulator score was taken into account as well, the total variance explained by the newly constituted model improved to 0.60 and misclassified only one patient with PD. The inclusion of more road-related tests, such as a driving simulator evaluation, should therefore be considered in the decision making process of driving cessation.

Our results are partially in contrast with previous findings.[5,7,10,12,13] Those five studies showed that driving safety was mainly determined by impaired neuropsychological performance rather than by motor dysfunc-

Table 4 Median, interquartile range (IQR) (Q1–Q3), and range for the driving simulator variables in patients with Parkinson disease (PD) and healthy individuals

	Patients with PD (n = 40)			Healthy individuals (n = 40)			Statistic	Significance level
Variable	Median	IQR	Range	Median	IQR	Range	w	*p* Value
TRIP driving simulator score (↑)	113	106.5–118	84–120	118	118–120	95–120	1,260	0.0008
Computerized measures								
Traffic offenses (↓)	1	0–2	0–7	0	0–1	0–1	1,970	0.0003
Accidents (↓)	0	0–1.5	0–3	0	0–1	0–3	1,744	0.18
Total number of traffic offenses and accidents (↓)	2	1–3	0–7	0	0–1	0–3	2,012	<0.0001
Divided attention								
Reaction times (s) (↓)	2.72	2.05–3.28	1.14–5	2.22	1.86–2.55	1.28–3.74	1,883	0.01
Omissions (↓)	7.5	2–12	0–28	4	2–8	0–22	1,799.5	0.08
Errors (↓)	2	1–3	0–9	2	1–4	0–8	1,575.5	0.67

Upward arrow means higher score better; downward arrow means lower score better.
w = Wilcoxon rank sum test; TRIP = Test Ride for Investigating Practical fitness to drive.

tion.[5,7,10,12,13] Our results indicate that driving performance in people with mild to moderate PD is affected by cognitive (CDR), visuo-integrative (contrast sensitivity), as well as motor deficits (UPDRS III), which is in line with previous research.[6,8,14,15] A possible explanation for the discrepancy might be that previous studies emphasized the inclusion of detailed neuropsychological measures to predict on-road performance.[5,7,10,12,13] In our study, the driving safety decision was made by a team of experts in assessing fitness to drive after a full assessment of visual, cognitive, and on-road tests and predicted by a series of general clinical tests.

This study was performed on a rather small group of patients with PD with minor cognitive deterioration. Our results therefore only relate to drivers with PD with relatively well preserved cognitive functioning. Apparently, this selection bias did not affect the inclusion of the CDR into the regression model, as it significantly differed between safe and unsafe drivers. We can assume that when more severely cognitively impaired drivers with PD were included into the study, the CDR would differentiate better between safe and unsafe drivers.

Future research should be conducted to explore the predictive accuracy of this model in a cohort of cognitively impaired drivers with PD. It would also be interesting to explore the contribution of motor symptoms (tremor, rigidity, bradykinesia) to different aspects of driving performance.

ACKNOWLEDGMENT

The authors thank the participants and the Flemish PD Society for their time and cooperation as well as the BIVV in general and the CARA staff in particular for the fitness to drive evaluations.

Received February 14, 2007. Accepted in final form April 27, 2007.

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