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Driving assessment in Parkinson's disease - A novel predictor of performance?

Richard Cordell, MBBS FRACP[1], Hoe C. Lee, PhD[2]*, Andrew Granger, MBChB FRACP[1], Barry Vieira, MBBS FRACP[1], Andy H. Lee, PhD[3]

[1]Parkinson's Disease Clinic, Osborne Park Hospital, Western Australia, Australia
[2] School of Occupational Therapy, Curtin University of Technology, Western Australia, Australia
[3] Department of Biostatistics and Epidemiology, School of Public Health, Curtin University of Technology, Western Australia, Australia

Abstract

Clinical symptoms of Parkinson's disease (PD) can make driving hazardous. The removal of the privilege to drive reduces independence; nevertheless, to protect public safety, medical practitioners require reliable screening tools to decide whether a PD driver should be on the road. The aims of this study were to examine whether clinical measures for PD patients and information provided by carers can be employed to predict impairment in driving performance. Fifty three idiopathic PD subjects and 129 age-matched controls were assessed on open roads. Prior to the driving assessment, participants were examined by a geriatrician. Various clinical measures of PD were recorded, and their carers filled out a questionnaire assessing driving ability of the patient. The driving performance of the participants declined with age ($r = 0.89$, $P < 0.001$). Drivers with PD were significantly less competent drivers than controls. The commonest errors committed on the road were indecisiveness in T-junctions and reduced usage of rear view and side mirrors. Only two of the clinical measures of PD patients showed links to driving performance. Information provided by carers was significantly related to driving performance of PD patients ($F_{(4,48)} = 3.87$, P-value < 0.01, $R^2 = 0.557$). PD drivers were less competent drivers than the age-matched control group; moreover, standard clinical measures of PD have little value in predicting their driving performance. Carers can provide valuable information to doctors in identifying unsafe PD drivers.

ARTICLE TEXT

Driving a car requires full coordination of physical and cognitive functions.[1] Symptoms of Parkinson's disease that could make driving hazardous include involuntary movements, bradykinesia, attention and information processing difficulties, and visuoperceptual function deficits.[2][3] Recently, auditory-verbal distraction and visual deficits were identified as having a strong impact on PD patients' driving ability.[4] PD drivers have previously acknowledged having difficulty in checking their blind spot, smooth handling of the car, and steering accurately.[4][5] In addition to numerous studies conducted in relation to sudden onset sleep, [6-12] several studies have examined the effect of PD on driving performance. Significant impairment in visual memory tasks, information processing capacity in a complex situation, and ability to change lanes were identified in PD groups.[4][5][13-15] Attempts have been made to establish relationships between standard clinical measures and driving performance of PD patients. Some reported that the Websters,[16] Hoehn and Yahr (H-Y), and Unified Parkinson's Disease Rating Scale (UPDRS)[17] linked with driving performance. However, Wood et al.[5] and Heikkilä et al.[18] found that poor driving ability did not correlate with any standard clinical scale, but found weak links to levodopa dose, age, and slowed visual processing and disease duration. The inconsistency could be due to small sample sizes of the studies in which researchers also employed limited aspects of driving skill to assess the overall ability of participating PD drivers. The findings may not fairly reflect the actual driving ability of the PD patients.

The ageing population will result in an increasing number of drivers with PD on the road, so being able to accurately assess the driving ability of this subgroup is essential. The removal of the privilege to drive could potentially have devastating effects on the liberty and self-esteem of a PD driver; however, public safety must also be considered in the decision-making. Heikkilä et al.[18] reported that 35% of the patients approved to drive by a neurologist were evaluated as unfit to drive in an on-road-assessment. Assessment for suitability to drive by medical practitioners is largely performed in outpatient settings using available standard clinical measures, relying largely on judgement and opinion, which can be inaccurate and unfair to the PD patients. In the current study, a comprehensive and multidimensional approach to assess PD drivers was adopted. Participants were assessed with a wide range of traffic scenarios and driving behaviors were captured by a well-established, multifaceted on-road scoring system.[19] In developing a composite score to represent the overall driving performance of individual participants, researchers took into consideration the interacting effects of many essential subskills of driving. The study was conducted to investigate whether standard clinical measures used to assess PD status, or information provided by a relative or carer, could be utilized in a clinical setting to predict PD patients' driving ability.

PATIENTS AND METHODS

Research Design

A one to three case-control single-blinded study design was adopted, targeting 50 PD patients with 150 age-matched healthy controls. All participants, aged between 60 and 80, were living in the community, not having incurred five or more demerit points in the past 2 years and driving at least 4 hours each week. All subjects were screened for acute, confounding medical and psychiatric conditions. Volunteers were excluded either if they scored less than 26 on the mini mental state examination (MMSE) or their visual acuity worse than 6 of 12 corrected on Snellen chart testing. The control group was randomly selected from the membership database of the *Council on the Aging* and screened for PD prior to driving assessment. The patient group was recruited from local specialist PD clinics and neurologists. Participants with PD had a confirmed diagnosis with no history or evidence of additional neurological impairment that may affect driving.

PROCEDURE

The study was approved by the Human Research Ethics Committee of the researchers' institution. The assessment procedure was explained to each participant prior to formal testing. Written consent was sought throughout the process and confidentiality of records was maintained. All participants were informed that they were free to terminate the study at any time without any negative consequences. Moreover, in the event of inadequate driving skill in the opinion of the principal investigator, counseling and advice would be provided to the subject if deemed necessary.

CLINICAL MEASURES

Prior to the driving assessment, the PD participants were examined by a geriatrician to ensure all driving and clinical tests were undertaken when the participants were optimally treated. Standard clinical measures for PD patients including the overall UPDRS, motor UPDRS, H-Y score, L-dopa equivalents, number of doses per day, MMSE, IQ code for dementia, Epworth Sleepiness Score, and Timed Up and Go Test were administered to all PD participants. The IQ code for dementia is used in the assessment of cognitive impairment with a score of 3.5 or greater suggesting a change in cognitive abilities. The Timed Up and Go Test is a marker of motor function in PD and is the time taken to stand from seated, walk 3 m around an object and return back to the original seated position. Information surrounding driving habits of each PD participant was collected during the 45-min initial screening.

Perceptions of Participant's Driving Ability

The PD participant and a carer, or relative, were asked to fill out separate questionnaires on perception of the participant's driving ability. The *Carer Questionnaire* (refer to Supplementary Figure 2), derived from questionnaires used in assessing drivers with dementia, emphasized the difficulties and safety of PD patients in driving. The content

validity of the questionnaire was verified by an expert panel, with members including neurologists, general practitioners, local police, traffic wardens, driver-trained therapists, driving instructors, and other stakeholders who have an interest in road safety. The analysis of the results of 10 convenient samples indicated that the answers provided by the carers were a better reflection of the on-road performance of PD patients.

Driving Performance Assessment

All personnel involved in the driving assessment were unaware of the medical conditions or the categorization of the participants. Driving performance was assessed in the participant's car along a 15-km route chosen by the participants in his/her neighborhood to cover a range of typical driving situations, such as roundabouts, traffic lights, pedestrian-crossings and T-junctions within 45 min. An accredited professional driving instructor, experienced in assessment of disabled drivers, sat in the front passenger seat and was responsible for maintaining vehicle safety. A driver-trained occupational therapist, experienced in the driving assessment and rehabilitation, sat in the rear seat. Both assessed driving ability of participants using well defined on-road assessment criteria.[19] For example, *Road Use Obligation* comprised of desirable driving behaviors such as giving appropriate signals, being certain of obligations in roundabouts, and being decisive to proceed when the opportunity arose. A procedure manual, together with specific on-road assessment scoring sheets (available upon request from the author), was used to ensure uniformity and consistency in the data collection process.

Data Analysis

All data were coded and analyzed using STAT version 8 (Stata Corporation, 2003).[20] The driving assessment criteria were first combined by principal component analysis to develop an overall *Road Assessment Index*. The performance index of a participant can be viewed as a weighted average score of the assessment criteria; a higher index score indicates a better overall driving performance. This method was previously validated[19][21] as a suitable method to aggregate multiple independent variables into a composition score representing overall driving performance of older drivers. Differences between patient and control groups were analyzed by independent t tests. Pearson correlation and stepwise linear regression were employed to investigate the relationships between clinical measures, the informant questionnaire and the driving ability of participants. Using driving performance of participants as the outcome measure, regression analysis was employed to check links among standard clinical measures for PD patients, age, gender, disease duration, and information provided by carers. Multivariate analysis was also adopted to investigate the interacting effect of various subskills in diving.

RESULTS

Characteristics of Patient and Control Groups

Fifty three patients with a diagnosis of idiopathic PD and 129 controls completed an on-road driving assessment. The drop-out rate was ~9% in both groups. No participant in the

control group was excluded from the study due to a history or current evidence of any medical or neurological impairment. Between the study groups, the mean age, driving experience in years, and driving exposure per week did not differ significantly ($P > 0.05$) and the characteristics of the participants were shown in Supplementary Table 1.

Driving Performance of PD Patients Versus Control Group

The control group performed better in all driving tasks, as indicated by a higher score in the corresponding assessment criteria (Supplementary Table 2). There are also significant negative correlations between the assessment criteria and the chronological age of individuals (Pearson Correlation, r between 0.79 and 0.89, $P < 0.001$). An inspection of Pearson correlations revealed that the assessment criteria were highly correlated with each setting, with r as high as 0.79 between some variables (correlation matrices available upon request from the author). Therefore, principal component analysis was undertaken to develop an overall *Road Assessment Index* for PD and control groups (refer to Supplementary Figure 3).

There are significant differences between the *Road Assessment Indices* ($t_{180} = 84.2$; $P <$ 000.1) in the patient and control groups. Supplementary Figure 1 shows the overall on road performance in the controls is better than patient group. The Road Assessment Index recorded by the occupational therapist and driving instructor on individual PD participants were highly correlated ($r = 0.86$, $P < 0.001$). The commonest errors committed on the road, by PD patients, were failing to check the blind spot, unsteady car speed, and erratic movement of steering wheel, signaling inappropriately to exit roundabouts, indecisiveness in T-junctions and reduced usage of rear view and side mirrors.

Predictive Value of the Clinical Measures and the Carer Questionnaire

A linear regression model was fitted to investigate the relationship between the *Road Assessment Index* and the total score of the *Carer Questionnaire*, adjusting for age, gender, and year since diagnosis. The assumptions underlying regression were checked and no apparent violation was found. The regression was found to be significant and the result of model fit is reported in Supplementary Table 3. Over 55% of the variability in the *Road Assessment Index* can be explained by the informant questionnaire. Interaction terms between variables were then included, but did not improve the goodness-of-fit of the model.

There are significant, but weak, correlations between the ADL subsection of UPDRS and Timed Up and Go Test with the *Road Assessment Index* (Pearson Correlation, r between 0.23 to 0.37, *P*-value < 0.001). When regression models were fitted to the two clinical measures, the R^2 is low, ranged from 0.283 to 0.313. Other standard clinical measures of PD severity, disease duration and numerical scores converted from a self-reported questionnaire filled out by the patient showed no significant correlation with driving performance.

DISCUSSION AND CONCLUSION

Driving is a dynamic activity, which requires synchronized patterns of actions such as application of the brake in anticipation of traffic accidents. To cater for the interaction effect of independent variables of driving tasks, researchers adopted a multivariate approach in developing the composition score for individual participants. The driving performance of the participants was confirmed to be negatively associated with age. This finding is consistent with the current literature that driving skills deteriorate gradually with age.[22] The on-road driving performance of the participants, assessed by the occupational therapist and driving instructor through identified assessment criteria and/or overall indices, confirmed that the controls performed more safely than the PD patients. The evidence that drivers with PD are significantly less competent drivers is supported by previous research.[13-15]

In the current study, it appears that participants with PD tended to drive more cautiously and less competently than control participants. The problems areas identified slowness in proceeding when they have the opportunity to do so in T-junctions, unable to control a steady speed, unsteady movement of the steering wheel, difficulty addressing two tasks in driving simultaneously and delayed decision and judgement. These problems probably stem from decreased motor skills, visuo-spatial processing, working memory and planning. According to the Michon model of car driving,[23] there are three major levels of driving behaviors. Strategic level behaviors often occur before driving such as planning the shortest route to the destination. Tactical level behaviors happen while driver responds to regulatory traffic signs. Operational level behaviors include second-to-second driving maneuvers in adjustment of car position to maintain reasonable distance from the car in front. When compared with the control, the PD patients did not perform well in both tactical and operational level. Future research could examine which level of behaviors contributes most to the poor performance of PD patients; consequently, effective compensatory strategies can be developed to help them staying on the road safely.

In our study, the overall driving performance of the PD participants could not be predicted by the overall UPDRS, motor UPDRS, H-Y score, L-dopa equivalents, number of doses per day, MMSE, IQ code for dementia, Epworth sleepiness score, and disease duration. Our results, like other studies on PD drivers, challenge the usefulness of these standard clinical measures, routinely used as markers of PD control and disease progression, in the assessment of driving ability. Decisions made on driving ability using these measures are likely to be inaccurate or unfair to PD patients or other road users, potentially letting unsafe PD drivers on the road.

The selfreported information from PD patient on their perception of ability in driving has little correlation with their actual driving performance. This finding confirms the conclusion of previous studies that it is unrealistic to expect individuals to determine their own driving ability.[5][17]

Importantly, the *Carer Questionnaire* findings suggest that other people can provide valuable information on PD driver's ability. Over half of the variability in the *Road Assessment Index* can be explained by our novel questionnaire. The questionnaire has the potential to be developed as a good predictor of driving performance in PD drivers. Comparison of the predictive value of the questionnaire to other recently assembled test battery[24] is one of the interesting aspects to pursue. This will be the objective of a larger study conducted by our research group, which includes a prospective longitudinal study to determine if the questionnaire can be used to identify problematic PD drivers, using their 3-year driver demerit points as the outcome measure.

The gender effect on the driving performance was not significant among the participants. However, it should be noted that the relatively small number of female participants does not reflect the actual gender distribution of older drivers. The current study involved one of the largest sample sizes of PD patients to date in on-road driving assessments; nevertheless, the participants who took part in this study cannot be taken as representative of the target-population because the sample was not randomly selected but only from some sectors of the community. Participants in this study had chosen to continue driving and had retained their licenses and are therefore likely to be better than average. The majority of the study sample were at H-Y stage 1 or 2, indicating their functional abilities were only minimally affected by the PD symptoms. The driving assessment was conducted during optimal on time medication and does not address the impact of symptom fluctuations in PD. Finally, the high predictive values of the *Carer Questionnair*e on the *Road Assessment Index* of PD participants can be confounded by the possibility of a carer bias. Answers could be influenced by the motivations behind them and the relationship with the patient. We kept the responses confidential from the patients to minimize potential conflict and would advocate similar practice in future studies.

In conclusion, this study confirms that PD drivers are significantly less competent drivers than control drivers; however, standard PD disease markers have little value in predicting their driving performance. Relatives or carers can provide valuable information on a PD driver's ability. Development of a tool, through which the driving behaviors of PD patient can be systematically collected and reliably recorded by relatives or carers, will help to identify unsafe PD drivers in a clinical setting.

Figure 1. Comparison of driving performance between patient and control groups.

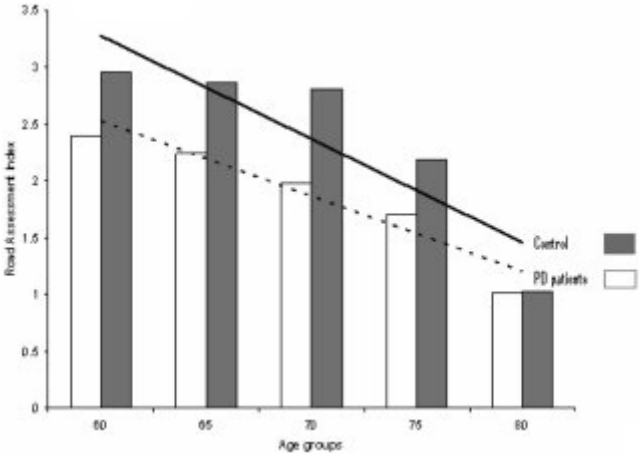

Figure 2. The Relative/Career Questionnaire on perception of participant's driving ability.

Do you feel uncomfortable in any way driving with the patient?
Have you noticed any abnormal or unsafe driving behaviour?
Has the patient had any crashes within the last 12 months?
Do you think the patient has difficulty in turning the steering wheel, changing gears, pressing the pedals?
Has the patient received any speeding tickets or traffic violations?
Are other drivers forced to drive defensively to accommodate the patient's errors in judgement?
Has the patient had near-misses that could be attributed to their Parkinson's disease?
Do you think the patient reacts too slowly to traffic situations?
Has the patient ever fallen asleep at the wheel since they were diagnosed with Parkinson's disease?
Have others commented on the patient's unsafe driving?
Do you think the patient is unsafe to drive?

*Scoring procedures: 11 questions to be asked by medical practitioner; one point for each "yes" answer; maximum possible score for each questionnaire is 11.

Figure 3. Box 2: Road Assessment Indices of PD and control groups

PD group's Road Assessment Index	*= 0.62*Error Detection + 0.55*Error Recovery + 0.78*General Driving Skill + 0.57*Normal Driving + 0.65*Road Use Obligation + 0.69*Traffic Sign Compliance + 0.54*Working Memory + 0.82*Use of Indicator + 0.52*Driving Speed + 0.67*T-Junction + 0.43*Traffic Light*
Control group's Road Assessment Index	*= 0.28*Error Detection + 0.15*Error Recovery + 0.36*General Driving Skill + 0.3*Normal Driving + 0.39*Road Use Obligation + 0.27*Traffic Sign Compliance + 0.22*Working Memory + 0.39*Use of Indicator + 0.31*Driving Speed + 0.36*T-Junction + 0.16*Traffic Light*

Table 1. Characteristics of the PD and control groups (Group means)

Item	PD patients, n = 53 Mean (SD); range	Control, n = 129 Mean (SD)
Percentage of males in the group	78	81
Age in years*	69.3 (8.3)	72.9 (7.1)
Driving experience in years*	42.5 (14.3)	43.7 (15.6)
Driving exposure in driving hrs/week*	8.7 (4.5)	9.2 (5.1)
Mini-Mental State Examination Score	29 (1.2)	30 (1.7)
IQ code for dementia	3.2 (0.4)	3.4 (0.6)
Disease duration in years	5.3 (5.6)	NA
Levodopa equivalents in mg	582 (355)	NA
Levodopa doses per day	3.1 (1.7)	NA
Epworth Sleepiness Score	10 (5.6); 2 to 24	NA
On-time total UPDRS	30 (12)	NA
On-time motor UPDRS	18 (8)	NA
On-time activity of daily living UPDRS	10 (4)	NA
Reaction time in seconds	7.28 (1.1)	NA
Timed Up and Go Test in seconds	9.3 (2.2)	NA
Hoehn and Yahr score#	1.6 (0.5); 1 to 3	NA
* t-test between groups not significant, $P > 0.05$. # 45% participants classified stage one, 54% classified stage two, and 1% classified stage three in H & Y score.		

Table 2. On-road driving tasks that differentiate the PD participants and controls

Tasks required to perform by the participants	Measure (maximum possible score)	Control, Mean (SD)/Experimental Mean (SD)
Road Use Obligation: Driving manoeuvres in seven roundabouts	Being certain of obligation, proceed when has opportunity to do so, give appropriate signals, give signal not too short or long, do not give wrong signal. (35)	21.2 (2.59)/17.2 (3.59)*
Traffic Sign Compliance: Manoeuvres through four pedestrian crossing, with a 5 mile/hr speed control sign and a speed bump	Slow down in approaching the crossing, do not stop when it is not necessary, do not hit the speed bumps, give way to pedestrians crossing and comply with the 5 mile/hr rule. (20)	13.9 (2.45)/9.7 (1.82)**

T-Junction: Manoeuvres before and through T-junctions	Do not approach intersection too slowly, do not brake or swerve at last minute, do not approach intersection too fast, look both ways in approaching intersection, do not proceed if way is not clear, proceed when has opportunity to, will give way (right hand rule), do not turn across oncoming traffic, do not swing too wide on corner, do not cut corner, do not swing too wide on corner and do not turn across oncoming traffic. (12)	5.78 (2.27)/4.56 (2.41)**
General Driving Skill: The steering and breaking behavior throughout the assessment	Erratic movement of the steering wheel, do not put arm and elbow out of window, do not allow steering wheel to self centre, do not incorrectly position their hand, do not depress clutch before brake in high gear while stopping, do not stop too far from given mark, do not stop too suddenly, do not stop too slowly in quick stop test and do not stall engine. (50)	40.8 (4.16)/34.8 (6.16)**
Traffic Light: Manoeuvres before and through traffic lights	Do not stop in wrong position, do not stop when not necessary, do not start before signal turns green, do not proceed on amber when could have stopped safely, do not proceed on red signal, do not cross continuous white line and do not fail to notice lights. (7)	5.17 (1.36)/4.89 (1.41)**
Normal Driving: General driving behaviour throughout the experiment	Keep to left, drive with reasonable speed, do not drive with erratic speed, do not take erratic course, use rear view mirror frequently, do not exceed speed limit, do not follow closely to the front car, do not overtake unnecessarily, do not veer over the centre line unless overtaking. (10)	7.41 (2.03)/6.43 (3.52)**
Use of Indicator: Correct use of indicators throughout the assessment	One point for each correct use of indicators. (27)	23.3 (2.45)/22.8 (2.13)*
* significant t-test, P-value < 0.01; **significant t-test, *P*-value < 0.001		

Table 3. Regression result for road assessment index (n = 53)

	Coefficient	S.E.	P-value
Constant	2.70	1.36	0.54
Informant questionnaire score	-1.53	0.06	0.01
Age (in years)	-0.33	0.02	0.08
Gender (male = 1, female = 0)	-0.02	0.35	0.95
Year since diagnosis	-0.03	0.02	0.29
$F^{(4,48)} = 3.87$, *P*-value < 0.01, $R^2 = 0.557$			

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