Parkinson disease and driving

An evidence-based review

Alexander M. Crizzle, PhD, MPH
Sherrilene Classen, PhD, MPH, OTR/L
Ergun Y. Uc, MD

Correspondence & reprint requests to Dr. Crizzle: acrizzle@sympatico.ca

ABSTRACT

The growing literature on driving in Parkinson disease (PD) has shown that driving is impaired in PD compared to healthy comparison drivers. PD is a complex neurodegenerative disorder leading to motor, cognitive, and visual impairments, all of which can affect fitness to drive. In this review, we examined studies of driving performance (on-road tests and simulators) in PD for outcome measures and their predictors. We searched through various databases and found 25 (of 99) primary studies, all published in English. Using the American Academy of Neurology criteria, a study class of evidence was assigned (I–IV, I indicating the highest level of evidence) and recommendations were made (Level A: predictive or not; B: probably predictive or not; C: possibly predictive or not; U: no recommendations). From available Class II and III studies, we identified various cognitive, visual, and motor measures that met different levels of evidence (usually Level B or C) with respect to predicting on-road and simulated driving performance. Class I studies reporting Level A recommendations for definitive predictors of driving performance in drivers with PD are needed by policy makers and clinicians to develop evidence-based guidelines. ***Neurology***® **2012;79:2067–2074**

GLOSSARY

ADL = activities of daily living; **AVLT** = Auditory Verbal Learning Test; **BVRT** = Benton Visual Retention Task; **CDR** = Clinical Dementia Rating Scale; **CDRS** = certified driving rehabilitation specialist; **H&Y** = Hoehn & Yahr; **HVLT** = Hopkins Verbal Learning Test; **JOLO** = Judgment of Line Orientation; **MMSE** = Mini-Mental State Examination; **PD** = Parkinson disease; **ROCF** = Rey-Osterrieth Complex Figure Test; **SDMT** = Symbol Digit Modalities Test; **UFOV** = Useful Field of View; **UPDRS** = Unified Parkinson's Disease Rating Scale.

In addition to the typical motor symptoms of Parkinson disease (PD), persons with PD may develop cognitive impairment/dementia, emotional impairments (e.g., apathy and disinhibition), and visual-perceptual deficits that often do not respond to dopaminergic medications.[1,2] Together with the variability in response to the timing of dosage (e.g., on-off phenomenon) and possible side effects (e.g., daytime sleepiness) of PD medications, these conditions can impair driving ability and potentially lead to elevated crash risk.[3,4]

The ability to drive safely may be impaired even in the early stages of PD.[5-17] Prior studies show that associations exist between impaired driving performance and deficits of contrast sensitivity,[13,16] visual processing,[5,10,16,17] set-shifting,[8,10,11,13] and psychomotor speed.[5,11-13,16] Epidemiologic data, however, are not well-established concerning crash rates in PD.[18-20] A retrospective survey study found that patients with Hoehn & Yahr (H&Y) stages 2 and 3 had a significantly higher crash risk compared to healthy controls. However, there was no evidence of increased crash risk among patients in H&Y stage 1.[20] Another survey study found that 82% of patients with PD held a driving license and 60% of them were still driving. Of the patients holding a driving license, 15% reported being involved in an accident, with 11% being at fault

Supplemental data at www.neurology.org

Supplemental Data

Podcast

From the Departments of Aging and Geriatric Research (A.M.C.) and Occupational Therapy (A.M.C., S.C.); Institute for Mobility, Activity and Participation (S.C.), University of Florida, Gainesville; Department of Neurology (E.Y.U.), University of Iowa; and Neurology Service (E.Y.U.), Veterans Affairs Medical Center, Iowa City, IA.

Study funding: This material is based upon work supported in part by the Department of Veterans Affairs, Veterans Health Administration, Office of Research and Development, Rehabilitation Research and Development (1-B6261R, Merit Review Award, PI: EYU, 2009–2011; 2-I01 RX000 170-01, Merit Review Award, PI: EYU, 2010–2012), and by National Institute of Neurological Disorders and Stroke grant R01 NS044930 (PI: EYU, 2003–2010) from NIH. The content of this manuscript is solely the responsibility of the authors and does not necessarily represent the official views of the granting agencies.

Go to Neurology.org for full disclosures. Disclosures deemed relevant by the authors, if any, are provided at the end of this article.

in the past 5 years.[21] However, whether crash rates are higher in PD is unclear as no age- and gender-matched controls were included for comparison purposes.[21] Recently, a prospective cohort study compared drivers with PD to drivers without neurologic conditions and found no clear link between PD and occurrence of real-life crashes.[22]

To date, there are no evidence-based practice parameters to guide physicians in determining driving fitness in PD. The American Medical Association recommends physicians base their decisions surrounding driving on both motor and cognitive impairments, response to dopaminergic medications, and side effects of medications.[23] Guidelines developed by the National Highway Traffic Safety Administration[18] and Federal Motor Carrier Safety Administration[24] suggest a case by case, multidisciplinary evaluation of the patient due to the highly individualized nature of the disease and variable progression. In the absence of clear guidelines, clinicians can only make subjective decisions on fitness to drive.[25,26] This may be problematic as physicians/neurologists often overestimate the driving ability of their patients with PD.[25-27] Additionally, drivers with PD may not reveal medical information when renewing their license or adhere to physician's advice to quit driving.[27]

Thus, it is critical to have guidelines for clinical decision making on driving ability in persons with PD. However, determining the level of evidence in prior PD and driving studies has proven difficult, primarily from the inconsistent results and various methodologic approaches used. In a recent review article, reasons for discrepant findings are related to 1) differences in sample sizes; 2) use of various rating scales; 3) heterogeneity of symptoms; 4) not stratifying by disease severity; and 5) varying driving performance measures.[26] The purpose of this current review is to discern the levels of evidence for reported predictors of driving fitness, using on-road and simulator studies, and to provide recommendations for driving performance.

METHODS We searched and analyzed the results of primary studies addressing PD and driving. Primary studies included only empirical and original peer-reviewed published manuscripts.[28] Specifically, we focused on the evidence used to determine driving ability and performance in persons with PD. We conducted the review using the following search criteria: a literature search, determining the inclusion/exclusion criteria, and ratings of the evidence and recommendations. We searched databases representing medicine, health science, psychological, and social science (e.g., PubMed, CINAHL, and Web of Science and Google Scholar) for key words, search terms, and MeSH headings including Parkinson's disease, driving, automobile, driving performance, driving ability, simulator, simulated, and road test. We also identified articles via footnote chasing (secondary sourcing). We excluded studies if they were 1) published prior to 1995 (due to the scant number of studies published before then); 2) duplicates; 3) not primary studies; 4) qualitative or descriptive; 5) of psychometric designs (e.g., test-retest, rater-reliability, or validity of measures); 6) not including driving as a primary outcome variable; 7) samples of a mixed composition (e.g., PD and Alzheimer disease); and 8) based on survey design. We included primary peer-reviewed articles published between 1995 and 2011 that reported empirical findings on driving performance and PD. The search yielded 57 citations with abstracts. After review, we excluded 32 as 9 were not primary studies; 11 did not use driving as an outcome measure; 3 were based on expert opinion; 3 were conducted prior to 1995; 2 were not in English; 3 were descriptive; and 1 was based on psychometric design. The remaining 25 studies met all criteria for inclusion and were critically appraised, classified, and synthesized.

Evidence-based ratings and recommendations. We used the classification criteria of the American Academy of Neurology to assign the level of evidence for studies examining drivers with PD.[29] These same guidelines were used to provide recommendations after studies were appropriately classified. As shown in table 1, we used the following parameters for rating an article by class (I–IV, with Class I being the highest level of evidence) and for making recommendations: Levels A–C (A being predictive or not of the outcome, B being probably predictive or not of the outcome, C being possibly predictive or not of the outcome) and Level U if inadequate data or conflicting findings existed. Classifications of studies and recommendations made were consistent among the 3 reviewers, with 92% agreement. We used team consensus to classify ratings for any studies that initially differed between raters.

RESULTS **Description of primary studies.** The 25 studies were published between 1998 and 2011. Thirteen studies reported federal or foundational funding. There were 16 on-road studies with PD sample sizes ranging from 19 to 154. Study design for on-road studies was primarily prospective (n = 15), with 1 retrospective study. Of the 9 simulator studies, 8 were experimental and 1 quasi-experimental. PD sample sizes ranged from 6 to 67. Disease severity of PD samples was considered to be mild to moderate across all studies. All studies included participants having a confirmed diagnosis of PD by neurologists or movement disorders specialists, although only 3 studies reported using the UK Brain Bank as a criterion for PD diagnosis.[5,16,29] Additionally, most studies evaluated participants for cognitive function. However, only 5 studies excluded participants based on cognitive screening. Four studies excluded those who scored ≤24 on the Mini-Mental State Examination (MMSE),[8,9,15,16] one study excluded those who scored

Table 1 AAN criteria for rating a study by class and making an evidence-based recommendation[29]

	Class I	Class II	Class III	Class IV
Rating article by class	Evidence provided by a prospective study in a broad spectrum of persons with the suspected condition, using a criterion standard for the case definition. Test should be applied in a blinded evaluation. All people undergoing the test have the presence or absence of the condition.	Evidence provided by a prospective study of a narrow spectrum of persons ($n < 100$) with the suspected condition, or a retrospective study of a broad spectrum of persons with an established condition by criterion standard, compared to a broad spectrum of controls.	Evidence provided by a retrospective study where either persons with the established condition or controls are of a narrow spectrum ($n < 100$). The reference standard, if not objective, is applied by someone other than the person performing the test.	Any design where the test is not applied in an independent evaluation or evidence provided by the expert opinion alone or in descriptive case series (without controls).
	Level A	**Level B**	**Level C**	**Level U**
Rating by recommendation	Recommendation: Established as effective/useful/or predictive or not. "Should be done, or should not be done."	Recommendation: Probably effective/useful/or predictive, or not. "Should be considered, or should not be considered."	Recommendation: Possibly effective/useful/or predictive, or not. "May be considered, or may not be considered."	No recommendation.
Condition for rating by recommendation	Requires 2 consistent Class I studies, or 1 Class I study where the magnitude of the effect is large, and all criteria have been met.	Requires at least 1 Class I study, or 2 consistent Class II studies.	Requires at least 1 Class II study, or 2 consistent Class III studies.	Data inadequate or conflicting. Given the current knowledge or test, the treatment is unproven.

AAN = American Academy of Neurology.

<26[7] on the MMSE, and one other study excluded those who scored ≤1 on the Clinical Dementia Rating Scale (CDR).[30]

Level of evidence, conclusions, and recommendations. A summary of the 25 primary studies included in this review, containing the title, authors, year and funding, primary objective, sample characteristics, independent and outcome variables, design, key findings, level of evidence, and conclusions, is shown in table e-1 on the *Neurology*® Web site at www.neurology.org. Based on the criteria outlined in table 1, results, conclusions, and recommendations concerning predictors of driving performance (on-road and simulator) are discussed next.

On-road studies. ***Result.*** The review yielded 12 Class II studies[5,7-13,15-17,25,30] and 4 Class III studies.[31-34] Only 2/16 on-road studies utilized a certified driving rehabilitation specialist (CDRS) to conduct the on-road tests.

Conclusion. From the 12 Class II studies, 11 studies found that drivers with PD had significantly worse driving performance ($p < 0.05$) than healthy controls.[5,7,8,10-13,15-17,25] No definitive conclusions could be made for one study as a control group was not included for on-road driving.[30] Although most drivers with PD were considered safe to drive, deficits that may affect driving were apparent even in the early stages of PD. There were 6 studies that found a clinical battery predicted driving performance[5,10,12,13,17,30] while one study did not.[9] Variables that predicted driving performance also differed across studies, as shown in table e-1. As findings were mixed concerning what clinical tests predicted driving performance, we examined and derived conclusions for predicting driving performance based on individual tests employed in studies (e.g., Useful Field of View [UFOV], MMSE).

Disease severity/duration. We concluded the Unified Parkinson's Disease Rating Scale (UPDRS) motor scores obtained while patients are on medication to be probably not predictive of driving performance based on 10 Class II[5,7,10-13,15-17] and 3 Class III studies.[31,32,34] However, based on 2 Class II studies,[5,17] UPDRS motor scores during the practically defined "off" period were concluded to be probably predictive of driving performance. We also concluded the H&Y stages to be probably not predictive of driving performance based on 4 Class II studies[5,15,16,30] and 2 Class III studies.[33,34] We concluded no recommendations could be made for the use of the Webster's rating scale. We considered disease duration to be probably not predictive of driving performance based on 6 Class II studies[12,13,15-17,28] and 1 Class III study.[31]

Vision tests. Six Class II studies[5,11-13,16,17] and 1 Class III study[31] assessed contrast sensitivity. Five studies used the Pelli-Robson chart (4 Class II[11-13,16] and 1 Class III[31]) and 2 Class II studies used the Optec 2500[5,17] to assess contrast sensitivity (scored as either acceptable or impaired). We concluded that contrast sensitivity was probably predictive of driving performance. Visual acuity was assessed in 6 Class II studies[5,10-13,16] and 1 Class III study.[31] While most studies found that visual acuity was not predictive of driving performance, 1 Class II study found that far visual acuity was predictive of at-fault errors on the road.[13]

Visual attention/perceptual/spatial tests. Seven studies included the UFOV (6 Class II and 1 Class III). From the 6 Class II studies,[5,10,12,13,16,17] we concluded the UFOV was probably predictive of impaired driving performance. Two Class II studies found the UFOV subtest 2 was probably predictive,[5,17] and 1 Class II[17] and 1 Class III study[32] found that the UFOV subtest

3 was possibly predictive of driving performance. Two Class II studies[5,10] found that the UFOV Global Risk Index of 3 (moderate crash risk) was probably predictive of differentiating between safe and unsafe drivers with PD. From 4 Class II studies,[10-13] we concluded that cumulative scores based on the 4 UFOV subtests were probably predictive of driving performance. Only one study had determined UFOV cutpoints,[17] as shown in table e-1.

Cognitive tests. We concluded the Rey-Osterrieth Complex Figure Test (ROCF) to be probably predictive of driving performance based on 6 Class II studies[8,10-13,30] and 1 Class III study.[31] The Trail Making Test Part B (Trails B) was used in 2 Class II[8,17] and 2 Class III studies.[31-33] We concluded that the Trails B is probably predictive of driving performance. We concluded the Trails A, used in 1 Class II study[8] and 2 Class III studies,[31-33] to be possibly predictive of driving performance. Four Class II studies[10-13] used Trails B–A (defined as time on Trails A subtracted from time on Trails B) and were found to be strongly associated with at-fault driving errors. We concluded that Trails B–A is probably predictive of driving performance. The MMSE, used in 6 Class II studies[5,7,12,13,17,25] and 2 Class III studies,[33,34] is probably not a useful predictor of driving performance in drivers with PD. We considered the CDR, Hopkins Verbal Learning Test (HVLT), Judgment of Line Orientation (JOLO), Benton Visual Retention Task (BVRT), and the Auditory Verbal Learning Test (AVLT) possibly predictive based on the results of 1 Class II study or 2 Class III studies.

Motor tests. We concluded that functional reach tests are probably predictive of driving performance based on 2 Class II studies.[11,13] Finger tapping, Pegboard test, Rapid Paced Walk test, and Timed Get Up and Go test are possibly predictive of driving performance determined by 1 Class II study and 2 Class III studies.

Recommendations. Level B: The UFOV subtest 2, Risk Index, cumulative UFOV scores (based on 4 subtests), contrast sensitivity, Trails B and B–A, ROCF, functional reach, and UPDRS "off" motor scores are probably predictive of driving performance. Conversely, UPDRS motor scores, H&Y, disease duration, Geriatric Depression Scale, and MMSE scores are probably not predictive of driving performance. Level C: UPDRS-activities of daily living (ADL) scores, Trails A, CDR, HVLT, JOLO, Wechsler Intelligence Test, BVRT, AVLT, Finger tapping, Rapid Paced Walk test, Timed Get up and Go test, and Pegboard test are possibly predictive of driving performance. Epworth Sleepiness Scale scores are possibly not predictive of driving performance. Level U: Age,[13,30,34] reaction time,[25,33] and Webster's Rating Scale[32] cannot be interpreted due to inadequate (tests used in 1 study[32]) or conflicting data.

Simulator studies. ***Result.*** The review yielded 9 Class III studies.[6,9,14,35-40]

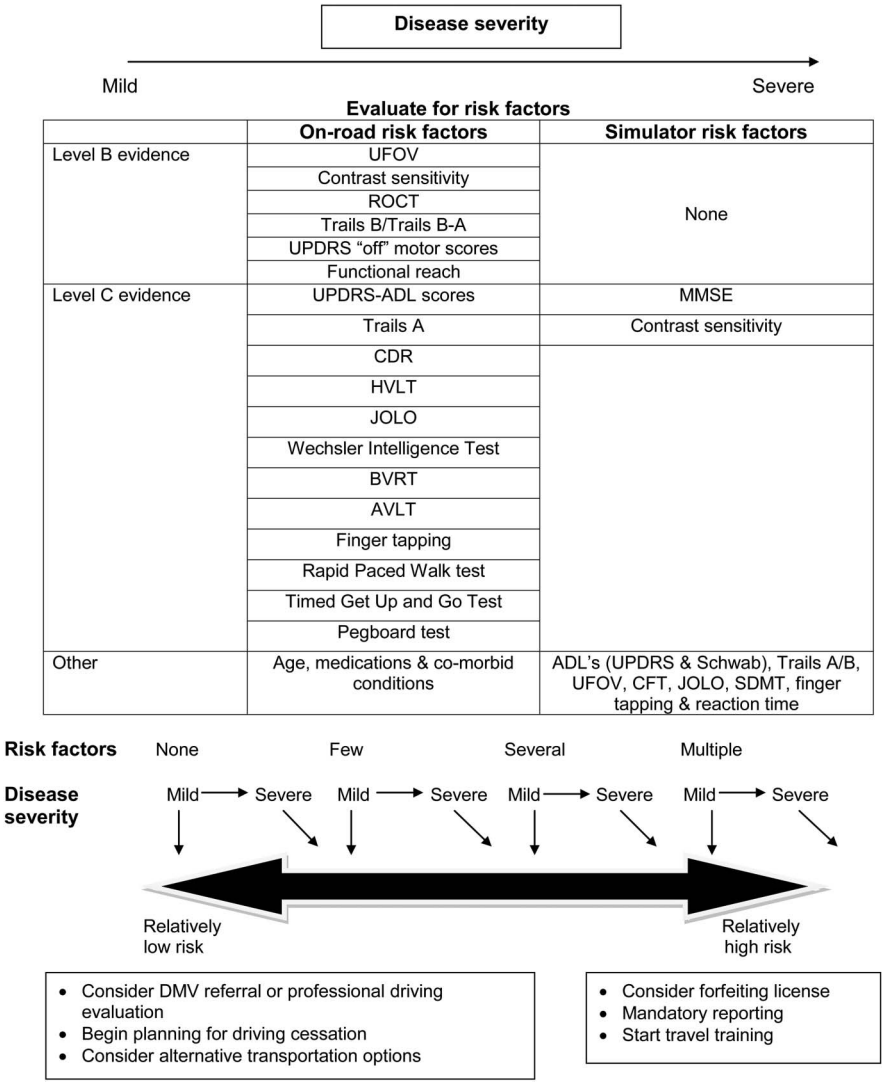
Conclusion. From the 9 Class III studies, we concluded that cognitive abilities may deteriorate even in mild to moderate stages of PD. Declining cognitive function was related to impaired simulated driving performance,[6,9,37,38,40] particularly in low visibility conditions (assessed using the Pelli-Robson chart).[14] Disease severity (H&Y) was associated with worse simulated driving performance.[35] The use of external cues may help improve skills related to driving.[39]

Recommendations. Level C: MMSE scores and contrast sensitivity (assessed via the Pelli-Robson Chart) are possibly predictive of simulated driving performance in the mild to moderate stages of PD. Level U: We could not make any recommendations with respect to age, UPDRS motor and ADL scores, H&Y, Schwab-ADL scores, Trails A and B, UFOV, ROCF, JOLO, Symbol Digit Modalities Test (SDMT), Finger tapping, or reaction time due to inadequate data (tests only used in 1 study).

DISCUSSION Based on the findings of this review, certain risk factors may be more heavily weighted than others when determining fitness to drive. Modified from a prior diagram,[41] the figure outlines a hierarchy of the primary findings of this review for both on-road and simulator studies. Increasing disease severity, in addition to risk factors (as concluded by this review), may provide a framework to help clinicians determine when drivers with PD are at risk. However, in the absence of a meta-analysis with pooled effect sizes to make clinical inferences, this information should be considered as supplemental to clinician's judgment.

While the figure provides a general baseline of risk factors concerning fitness to drive, when a person may reach a high level of risk is unclear. Besides UFOV risk index score, which needs to be replicated in larger studies, we cannot suggest any cutoffs for the remaining risk factors that would indicate a high-risk driver or a patient with PD who should discontinue driving. Future studies are needed to determine cutpoints of risk factors with on-road driving performance (e.g., sensitivity, specificity, negative predictive value, and positive predictive value) and prospective crash risk. In the absence of definitive cutpoints to help clinicians determine fitness to drive, we recommend patients in question be referred for a multidisciplinary evaluation (e.g., a team consisting of neurologist, neuropsychologist, CDRS), which includes a comprehensive driving evaluation. If the patient is unwilling or unable to take the evaluation by a CDRS (e.g., no insurance coverage for CDRS evaluation), a referral can be made to the state Department of Motor Vehicles for a road driving test.[42]

Figure Flow diagram



ADL = activities of daily living; AVLT = Auditory Verbal Learning Test; BVRT = Benton Visual Retention Task; CDR = Clinical Dementia Rating Scale; DMV = Department of Motor Vehicles; MMSE = Mini-Mental State Examination; ROCT = Rey-Osterrieth Complex Figure Test; HVLT = Hopkins Verbal Learning Test; JOLO = Judgment of Line Orientation; SDMT = Symbol Digit Modalities Test; UFOV = Useful Field of View.

We found no standard clinical battery to predict driving performance in drivers with PD. Clinical tests and in some instances neuropsychological tests differ from study to study and are administered on small PD samples. Moreover, studies have differed in their methods and evaluation of driving performance (e.g., CDRS, driving evaluator, driving instructor, research assistant). Some studies used instrumented vehicles, while others did not. Many studies also did not provide pass/fail outcomes on the on-road tests leading to difficulties interpreting what is truly considered "impaired driving performance."

From the on-road studies, we concluded that Level B evidence exists for the UFOV (subtest 2, risk index and cumulative across the 4 subtests), contrast sensitivity, Trails B and B–A, ROCF, Functional Reach, and UPDRS "off" motor scores for probably predicting driving performance. However, UPDRS "off" motor scores may not be a clinically useful predictor of driving performance as driving is usually assessed during the "on" state. Still, the predictive ability of these "off" period scores, as a measure of general motor severity of PD, rather than a snapshot of motor function in a compensated state, indicates the important influence of severity of parkinsonism on driving. A longitudinal study showing that UPDRS-ADL scores and the daily antiparkinsonian medication predicted future driving cessation supported this view.[22] However, given that studies have shown mixed results concerning impaired driving performance in drivers with PD, we recommend the need for Class I studies with Level A recommendations.

As visual attention, spatial, and executive skills are critical abilities for driving in general, it is not surprising that UPDRS "on" motor scores, H&Y, and disease duration are probably not predictive of driving performance. Disease severity indices mainly capture motor symptoms and do not capture visual or cognitive deficits. Additionally, deficits of visual and cognitive abilities may occur independently of motor symptoms.[43] Moreover, performance on basic visual sensory tests may be associated with performance on more complex visual cognitive tests.[2] Therefore, multivariate modeling of predictors (rather than just bivariate correlations) is critical to assess independent predictive contributions of different interrelated measures.

Of the 9 simulator studies examined in this review (all Class III), we found that cognitive deficits may be present in the early stages of PD, consistent with reported findings that suggest 20% have mild cognitive impairment at time of PD diagnosis.[44] We found simulated driving performance in drivers with PD to be worse in low contrast conditions, which may possibly be predicted by deficits of contrast sensitivity. We also determined the MMSE to be possibly predictive of simulated driving performance. However, caution is warranted as we could only make Level C recommendations. Additionally, the MMSE has been shown to be a poor predictor of on-road performance in drivers with PD.[5,15,25,45]

Differences between various simulator studies in technical characteristics (e.g., desktop simulator with 60-degree field of view[35] vs medium-high fidelity simulator with 180-degree field of view[9,37,38]) and the primary outcomes, as well as a lack of validity due to the various types of simulators used in prior studies, are also a concern. However, simulators can be used to determine predictors of driving performance that cannot be tested on the road test due to ethical, safety, and practical reasons (e.g., night, high volume traffic, poor weather conditions, or hazardous experiments where rapid reactions are needed). For example, in a simulated collision avoidance experiment, motor measures (UPDRS motor scores, tapping speed) were associated with time to first reaction to the hazard in a simulated collision avoidance.[16] Predictors identified on the simulator can be further tested on the road although follow-up studies are needed to discern the concurrent validity between on-road tests and simulators. We could not make a recommendation for age, UPDRS motor and ADL scores, H&Y, Schwab ADL scores, Trails A and B, UFOV, ROCF, JOLO, SDMT, Finger tapping, and reaction time.

In addition to psychometric and motor measures, factors such as driving records, exposure, and habits (e.g., use of compensation strategies), and input from caregivers[7] can be useful in determining driving outcomes in PD, especially driving cessation.[22] However, these measures are largely based on self-report and subject to associated methodologic problems. As an alternative, longitudinal "naturalistic" driving studies have the potential to improve prediction of driving outcomes by providing continuous, objective, and quantitative measures of driving in the patient's own vehicle and environment over a long time period while performing real-life tasks.[46]

The study limitations include making recommendations despite the small, heterogeneous, and male-dominated samples among the primary studies. We only searched and included studies published in English and those within the last 13 years. Although we searched for secondary sources, we did not pursue government publications, unpublished manuscripts, or disseratations.[28] However, to our knowledge, this is the first evidence-based review on driving on-road and simulated performance in PD. The strengths of this study include a team consensus process for study selection and expertise in evidence-based approaches, driving research, or PD.

Class I studies are needed to develop more effective screening tools for clinicians to identify at-risk drivers with PD. Class I studies with large and representative samples, standardized evaluation batteries, and driving protocols are needed to provide Level A recommendations to ultimately help policy makers and clinicians develop evidence-based decision guidelines.

AUTHOR CONTRIBUTIONS

Dr. Crizzle was responsible for the conceptualization and study design, data collection and analysis, interpretation and drafting the original manuscript, and subsequent revisions to the manuscript. Dr. Classen provided contributions to the study design, data analysis, interpretation of study findings, and editing first and all subsequent drafts of the manuscript. Dr. Uc provided expertise on data analysis and interpretation, and critically reviewed, edited, and revised all drafts of the manuscript.

DISCLOSURE

A. Crizzle reports no disclosures. S. Classen receives support from the National Parkinson's Foundation [NPF 00085107 (Project PI)]. E. Uc is receiving research support from Rehabilitation Research and Development Branch, Department of Veterans Affairs as the PI of the Merit Review awards on aerobic exercise in PD (1 I01 RX000170) and driving rehabilitation in PD (B6918). He has received research support from the NIH as the PI of the project "Predicting Driver Safety in PD" (R01 NS044930). **Go to Neurology.org for full disclosures**.

Received March 11, 2012. Accepted in final form July 25, 2012.

REFERENCES

1. Riggeal BD, Crucian GP, Seignoural PS, et al. Cognitive decline tracks motor progression and not disease duration in Parkinson disease. Neuropsychiatr Dis Treat 2007;3:955–958.
2. Uc EY, Rizzo M, Anderson SW, Qian S, Rodnitzky RL, Dawson JD. Visual dysfunction in Parkinson disease without dementia. Neurology 2005;65:1907–1913.
3. Uitti RJ. Parkinson's disease and issues related to driving. Parkinsonism Relat D 2009;15:A122–A125.
4. Uc EY, Rizzo M. Driving and neurodegenerative diseases. Curr Neurol Neurosci Rep 2008;8:377–383.

5. Classen S, Witter DP, Lanford DN, et al. Usefulness of screening tools for predicting driving performance in people with Parkinson's disease. Am J Occup Ther 2011;65:579–588.
6. Chee D, Lee H, Flakmer T. Cognitive overload and its effects on driving performance in people with Parkinson's disease. In: 12th International Conference on Mobility and Transport for the Elderly and Disabled Persons. Hong Kong: 2010.
7. Cordell R, Lee HC, Granger A, Vieira B, Lee AH. Driving assessment in Parkinson's disease: a novel predictor of performance? Mov Disord 2008;23:1217–1222.
8. Grace J, Amick MM, D'Abreu A, Festa EK, Heindel WC, Ott BR. Neuropsychological deficits associated with driving performance in Parkinson's and Alzheimer's disease. J Int Neuropsychol Soc 2005;11:766–775.
9. Stolwyk RJ, Triggs TJ, Charlton JL, Iansek R, Bradshaw JL. Impact of internal versus external cueing on driving performance with Parkinson's disease. Mov Disord 2005;20:846–857.
10. Uc EY, Rizzo M, Anderson SW, Sparks J, Rodnitzky RL, Dawson JD. Impaired visual search in drivers with Parkinson's disease. Ann Neurol 2006;60:407–413.
11. Uc EY, Rizzo M, Anderson SW, Sparks JD, Rodnitzky RL, Dawson JD. Driving with distraction in Parkinson disease. Neurology 2006;67:1774–1780.
12. Uc EY, Rizzo M, Anderson SW, Sparks JD, Rodnitzky RL, Dawson JD. Impaired navigation in drivers with Parkinson's disease. Brain 2007;130:2433–2440.
13. Uc EY, Rizzo M, Johnson AM, Dastrup E, Anderson SW, Dawson JD. Road safety in drivers with Parkinson disease. Neurology 2009;73:2112–2119.
14. Uc EY, Rizzo M, Anderson SW, Dastrup E, Sparks JD, Dawson JD. Driving under low-contrast visibility conditions in Parkinson's disease. Neurology 2009;73:1103–1110.
15. Wood JM, Worringham C, Kerr G, Mallon K, Silburn P. Quantitative assessment of driving performance in Parkinson's disease. J Neurol Neurosurg Psychiatry 2005;76:176–180.
16. Worringham CJ, Wood JM, Kerr GK, Silburn PA. Predictors of driving assessment outcome in Parkinson's disease. Mov Disord 2006;21:230–235.
17. Classen S, McCarthy DP, Shechtman O, et al. Useful field of view as a reliable screening measure of driving performance in people with Parkinson's disease: results of a pilot study. Traffic Inj Prev 2009;10:593–598.
18. National Highway Traffic Safety Administration (NHTSA). Driver Fitness Working Group of the American Association of Motor Vehicle Administrators (AAMVA). Driver fitness medical guidelines [online]. Available at: http://www.nhtsa.gov/DOT/NHTSA/Traffic%20Injury%20Control/Articles/Associated%20Files/811210.pdf. Accessed March 6, 2012.
19. Homann CN, Suppan K, Homann B, Crevenna R, Ivanic G, Ruzicka E. Driving in Parkinson's disease: a health hazard? J Neurol 2003;250:1439–1446.
20. Dubinsky RM, Gray C, Husted D, et al. Driving in Parkinson's disease. Neurology 1991;41:517–520.
21. Meindorfner C, Korner Y, Moller JC, Stiasny-Kolster K, Oertel WH, Kruger HP. Driving in Parkinson's disease: mobility, accidents, and sudden onset of sleep at the wheel. Mov Disord 2005;20:832–842.
22. Uc EY, Rizzo M, Johnson AM, et al. Real-life driving outcomes in Parkinson's disease. Neurology 2011;76:1894–1902.
23. American Medical Association, National Highway Traffic Safety Administration. Physician's guide assessing counseling older drivers [online]. Available at: http://www.ama-assn.org/ama/pub/physician-resources/public-health/promoting-healthy-lifestyles/geriatric-health/older-driver-safety/assessing-counseling-older-drivers.page. Accessed August 24, 2012.
24. Caruso G, Dawson J, DeLuca J, Marcotte TD, Rizzo M. Opinions of expert panel: Parkinson's disease, multiple sclerosis, and commercial motor vehicle driver safety. Federal Motor Carrier Safety Administration, 2009. Available at: http://www.fmcsa.dot.gov/rules-regulations/TOPICS/mep/report/PD_MS_MEP_Opinions_09212009.pdf.
25. Heikkila VM, Turkka J, Korpelainen J, Kallanranta T, Summala H. Decreased driving ability in people with Parkinson's disease. J Neurol Neurosurg Psychiatry 1998;64:325–330.
26. Klimkeit EI, Bradshaw JL, Charlton J, Stolwyk R, Georgiou-Karistianis N. Driving ability in Parkinson's disease: current status of research. Neurosci Biobehav Rev 2009;33:223–231.
27. Cubo E, Martin PM, Gonzalez M, et al. What contributes to driving ability in Parkinson's disease. Disabil Rehabil 2010;32:374–378.
28. Cooper HM, Hedges LV. The Handbook of Research Synthesis. New York: Russell Sage Foundation; 1994.
29. Edlund W, Gronseth G, So Y, Franklin G. Clinical Practice Guideline Process Manual. St Paul: American Academy of Neurology; 2004.
30. Devos H, Vandenberghe W, Nieuwboer A, Tant M, Baten G, De Weerdt W. Predictors of fitness to drive in people with Parkinson disease. Neurology 2007;69:1434–1441.
31. Amick MM, Grace J, Ott BR. Visual and cognitive predictors of driving safety in Parkinson's disease patients. Arch Clin Neuropsychol 2007;22:957–967.
32. Radford K, Lincoln N, Lennox G. The effects of cognitive abilities on driving in people with Parkinson's disease. Disabil Rehabil 2004;26:65–70.
33. Singh R, Pentland B, Hunter J, Provan F. Parkinson's disease and driving ability. J Neurol Neurosurg Psychiatry 2007;78:363–366.
34. Amick MM, D'Abreu A, Moro-de-Casillas ML, Chou KL, Ott BR. Excessive daytime sleepiness and on-road performance in patients with Parkinson's disease. J Neurol Sci 2007;252:13–15.
35. Zesiewicz TA, Cimino CR, Malek AR, et al. Driving safety in Parkinson's disease. Neurology 2002;59:1787–1788.
36. Vaux LM, Ni R, Rizzo M, Uc EY, Andersen GJ. Detection of imminent collisions by drivers with Alzheimer's disease and Parkinson's disease: a preliminary study. Accid Anal Prev 2010;42:852–858.
37. Stolwyk RJ, Charlton JL, Triggs TJ, Iansek R, Bradshaw JL. Neuropsychological function and driving ability in people with Parkinson's disease. J Clin Exp Neuropsychol 2006;28:898–913.
38. Stolwyk RJ, Triggs TJ, Charlton JL, Moss S, Iansek R, Bradshaw JL. Effect of a concurrent task on driving performance in people with Parkinson's disease. Mov Disord 2006;21:2096–2100.
39. Scally K, Charlton JL, Iansek R, Bradshaw JL, Moss S, Georgiou-Karistianis N. Impact of external cue validity on driving performance in Parkinson's disease. Parkinsons Dis 2011;2011:159621.
40. Ranchet M, Paire-Ficout L, Marin-Lamellet C, Laurent B, Broussolle E. Impaired updating ability in drivers with Parkinson's disease. J Neurol Neurosurg Psychiatry 2011;82:218–223.

41. Iverson DJ, Gronseth GS, Reger MA, Classen S, Dubinsky RM, Rizzo M. Practice parameter update: evaluation and management of driving risk in dementia: report of the Quality Standards Subcommittee of the American Academy of Neurology. Neurology 2010;74:1316–1324.
42. Rizzo M. Impaired driving from medical conditions: a 70-year-old man trying to decide if he should continue driving. JAMA 2011;305:1018–1026.
43. Chaudhuri KR, Healy DG, Schapira AH. Excellence NIfC. Non-motor symptoms of Parkinson's disease: diagnosis and management. Lancet Neurol 2006;5:235–245.
44. Aarsland D, Bronnick K, Williams-Gray C, et al. Mild cognitive impairment in Parkinson's disease: a multicenter pooled analysis. Neurology 2010;75:1062–1069.
45. Crizzle AM, Classen S, Bédard M, Lanford D, Winter S. MMSE as a predictor of on-road driving performance in community dwelling older drivers. Accid Anal Prev (in press 2012).
46. Rizzo M, Uc EY, Dawson J, Anderson S, Rodnitzky R. Driving difficulties in Parkinson's disease. Mov Disord 2010;25:S136–S140.

This Week's *Neurology*® Podcast

Parkinson disease and driving: An evidence-based review **(See p. 2067)**

This podcast begins and closes with Dr. Robert Gross, Editor-in-Chief, briefly discussing highlighted articles from the November 13, 2012, issue of Neurology. In the second segment, Dr. John Morgan talks with Dr. Alex Crizzle about his paper on Parkinson disease and driving. Dr. Stacey Clardy reads our e-Pearl of the week about tumarkin attacks-the otolithic catastrophe. In the next part of the podcast, Dr. Ted Burns focuses his interview with Steven Lewis and Allison Weathers on electrolytes and other metabolic disorders. Disclosures can be found at www.neurology.org.

At www.neurology.org, click on the "Download Latest Issue" link or "Subscribe Now" to subscribe to the RSS Feed.

CME Opportunity: Listen to this week's Neurology® Podcast and earn 0.5 AMA PRA Category 1 CME Credits™ by answering the multiple-choice questions in the online Podcast quiz.