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Research Article

Parkinson's Disease and Lewy Body Dementia and Driving: A Review of the Literature

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Abstract

There is significant research about Parkinson's disease and driving, however, very little is known about Lewy Body dementia and driving ability, though the two diseases are closely linked. The purpose of this study was to review the literature about Parkinson's disease and driving and Lewy Body dementia and driving. Articles from 1993-2013 that were published in English, used human data, and made a connection between Lewy body dementia and driving or Parkinson's disease and driving were used in the final review. The following databases were searched: EBSCOhost, PubMed, Google Scholar, Proquest, Web of Knowledge, and Publishing Connect. One article about Lewy Body dementia and driving was located that met the inclusion criteria, whereas 21 articles met the inclusion criteria for Parkinson's disease and driving. Results indicate that drivers with Parkinson's disease perform poorly behind the wheel compared to healthy matched controls, thus fitness to drive should be questioned.

Keywords: Lewy body dementia, Parkinson's disease, Driving, Crash, Older drivers

Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disease that affects motor function and cognitive abilities [1]. Parkinson's disease accompanied by dementia can be common in many patients. Explicitly, around one third of people with Parkinson's disease will also develop dementia [2]. In some cases, there is a pathological existence of both Parkinson's disease with Alzheimer's disease [2]. However, many patients with Parkinson's disease may also experience dementia attributable to the manifestation of Lewy bodies in the neurons of the cerebral neocortex [2]. Following Alzheimer's disease, Lewy Body dementia is the second most common form of neurodegenerative dementia [3]. There are three core features for diagnosis of Lewy Body dementia: vacillating cognition with a noticeable variation in attention span/alertness, consistent manifestation of well-formed and detailed visual hallucinations, parkinsonism movements that occur spontaneously [2]. If a patient manifests with two of these core features, a diagnosis of probable Lewy body dementia is expected, while patients with just one core feature present for a diagnosis of possible Lewy Body dementia [2]. Contrasting with Alzheimer's disease, memory impairment is not usually a prominent early feature of Lewy Body dementia. Alternatively, impairments in executive function, visuospatial ability, and attention are often seen in patients with Lewy Body dementia [2].

Given the impact of Lewy Body dementia on executive function, clear consequences on cognitively demanding tasks like driving are expected. Driving involves motor coordination, tracking of other vehicles, quick reaction time, planning, judgment, and attentional tasks [4]. Safe driving requires a driver to perform these multiple tasks, be aware of simultaneous ongoing events, and monitor traffic and pedestrians visually [4]. Because Lewy Body dementia impairs planning, judgment, and other cognitive abilities, driving status should be questioned and tested in these patients. Currently, there is only one study that mentions Lewy Body dementia and driving, so the literature in this area is in credibly dearth.

There is however, growing evidence that people with Parkinson's disease are at an increased risk for hazardous driving [5-9]. One simulated driving study found that drivers with Parkinson's disease have exhibited reduced driving performance

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including longer reaction time to traffic light changes, inability to steer accurately, and a more collisions than controls [9]. Further, one on road study of driving ability found that participants with Parkinson's disease engaged in more risky faults and offence than controls including difficulty driving in heavy traffic flow, turning across traffic at an intersection, and driving in urban areas [8]. Moreover, drivers with Parkinson's are more likely to make incorrect turns and get lost and reduce usage of side and rear view mirros [9] compared to neurologically normal older adults [10]. Because Parkinsonian features are a core piece of Lewy Body dementia diagnosis, this study intended to review what is known about Lewy Body dementia and driving and Parkinson's disease and driving.

Methods

A review of the literature and state of science on Lewy body dementia and driving and Parkinson's disease and driving was conducted in order to better understand the scope of the problem of LBD/PD and driving. Further, this review was conducted to bring attention to the issue of LBD and driving, so that other researchers can become attuned to the issue.

Literature search

The following strategy was used to identify usable articles for the literature review. First relevant electronic databases were searched including: Academic Search Premier, AgeLine, CINAHL, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Cochrane Methodology Register, ERIC, Health and Psychosocial Instruments, Health Technology Assessments, MEDLINE, Primary Search, PsycARTICLES, PsycINFO, SocINDEX, Pubmed, Google Scholar, Proquest, Web of Knowledge and Publishing Connect. The following search terms were used Lewy body dementia /Parkinson's disease and driving, Lewy body dementia /Parkinson's disease and driving accidents, Driving cessation and Lewy body dementia /Parkinson's disease, Lewy body dementia /Parkinson's disease and automobile crashes, Lewy body dementia /Parkinson's disease and crashes, Lewy body dementia /Parkinson's disease and automobile, Lewy body dementia /Parkinson's disease and car, Neurodegenerative diseases and driving, Lewy body dementia /Parkinson's disease and caregiver. Additionally, key journals were searched directly: including the Journal of Geriatric Psychiatry &Neurology and The American Journal of Neurology. Articles from 1993-2013 that were published in English, used human data, and made a connection between Lewy body dementia and driving or Parkinson's disease and driving were used in the final review. A higher order search term approach was used to ensure that studies with both Lewy body dementia/ Parkinson's disease and driving were located and included in the review.

Inclusion/exclusion criteria

A study was included in the literature review if they met the following criteria: published from 1993-2013, published in English, were based solely on human research not animal research, included either Lewy body dementia and driving or Parkinson's disease and driving, within the same article. Studies were excluded if they were not in English, were based on animal research, and did not make a connection between either Lewy body dementia and driving or Parkinson's disease and driving within the same article. The authors' primary language proficiency was English, thus only studies in English were used for the review.

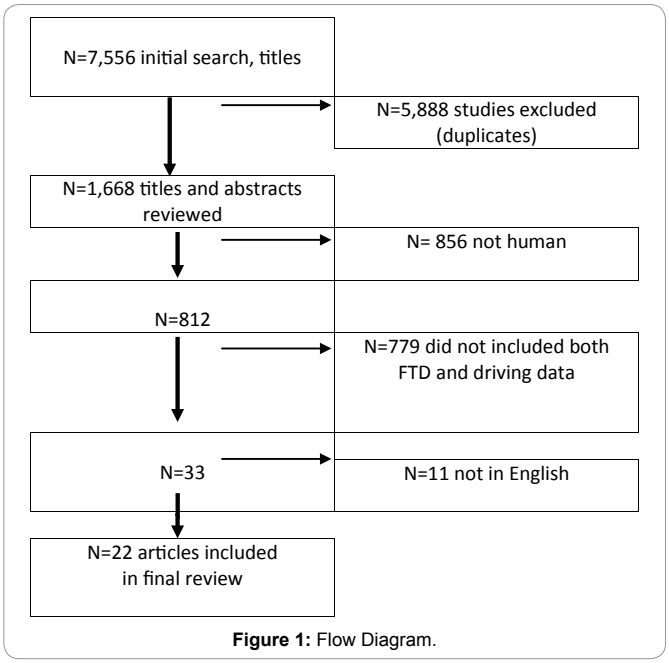

Figure 1: Flow Diagram.

A total of 7,556 titles and abstracts were reviewed. As seen in Figure 1, the Flow Diagram shows that duplicate articles were excluded (5,888) bringing the total for review to 1,668. A total of 856 studies were excluded due to not involving human subjects leaving the total at 812. A total of 779 articles were excluded for not reporting Lewy body dementia or Parkinson's disease and driving leaving the total to 33. Eleven of the last 33 studies had to be left out of the review because they were not available in English. The final number of studies used for this literature review was 22 studies.

Article evaluation

Based on the Downs and Black (1998) checklist for the assessment of the methodological quality of both randomized and non-randomized studies of health care interventions, I used 6 indicators to score each article on quality. The article was given one point per item that it satisfied. The items used from Downs and Black were: 1) Is the hypothesis/objective of the study clearly described? 2) Are the main outcomes to be measured clearly described in the Introduction or Methods section? 3) Are the characteristics of the patients included in the study clearly described? 4) Are the main findings of the study clearly described? 5) Were the subjects asked to participate in the study representative of the entire population from which they were recruited? 6) Were the statistical tests used to assess the main outcomes appropriate? (Table 1)

Results

Lewy body dementia and driving

Only one article addressed Lewy Body dementia and driving within the same article [11]. The authors of the article studied autopsied brains of people who died of motor vehicle accidents and compared them to the brains of older adults who died of other causes. The authors were attempting to isolate whether or

not those who died in a motor vehicle accident had pathological plaques and tangles associated with Alzheimer's, Lewy Bodies, and vascular lesions associated with multi infarct dementia. The authors concluded that there was no evidence of Lewy Bodies or vascular lesions in the brains of those who died of motor vehicle accidents, however neuritic plaques associated with Alzheimer's disease were found more frequently in the brains of those who died of a motor vehicle accident compared to those who died of other causes. This article was rated a 5 out of 6 possible points because some of the findings were somewhat unclear.

This exhaustive search only turned up one article published with both driving data and Lewy Body dementia in the last 20 years. This highlights the need for more research about Lewy Body dementia and driving. Because depression, sleep disorders, parkinsonian motor disturbances, arousal disturbances, hallucinations, and delusions are common behavioral and psychological symptoms of Lewy body dementia, individuals with this dementia should not be behind the wheel [10]. Furthermore, auditory hallucinations and somatosensory hallucinations may also occur in individuals with Lewy body dementia causing issues

Author	PD or LBD	Number of subjects	Study Design	Main Findings	Limitations	Notes	Quality Rating
1. Gorrie, C.A. et al. 2007	LBD	27 participants 28 controls	Neuropathological Assessment	Only a relatively small percentage of older drivers killed in motor vehicle accidents have moderate or severe AD-related pathology.	The finding of an increase of mild neuritic pathology in the brains of fatally injured older drivers is based on a small sample from a single geographic area.	Study was supported by funding from the Motor Accidents Authority, NSW	4/6 Findings somewhat unclear Small sample
2. Anderson SW, et al. 2012	PD	345 participants	Neuropsychological Tests, Visual Sensory Functioning tests, Road Test	Performances on all neuropsychological tests were significantly correlated with driving safety errors. Confirmatory factor analysis was used to identify 3 key cognitive domains assessed by the tests (speed of processing, visuospatial abilities, and memory), and several brief batteries consisting of one test from each domain showed moderate corrected correlations with driving performance.	All drives in the study were completed during in good weather conditions, daylight hours, and during non rush hour times. The design also did not allow the consideration of the drivers' strategic approach to driving, which may or may not include self-restriction to good driving conditions. Used limited choice of psychological tests.	N/A	6/6
3. Cubo, Esther, et al., 2010	PD	98	Driving status assessment, neuropsychological tests	Compared with the drivers, the ex-drivers were older, had longer disease duration, had more overall cognitive dysfunction, and had greater motor impairment, and difficulty in activities of daily life. In the regression model analysis, aging and ADL impairment were the principal clinical predictors that differentiated drivers from ex-drivers.	The main limitations were the cross-sectional design, the sample size (particularly the ex-drivers), lack of comparison with control subjects and lack of an objective gold- standard test (driving simulator, real driving test on the roads), to be able to correlate the clinical data obtained with driving when establishing the ability to drive and its safety.	The ELEP is supported by a grant from the Intramural Research Program, Carlos III Institute of Health Institute of Health.	4/6 Characteristics of the patients in the study were not clearly described and the subjects asked to participate were not representative
4. Devos, Hannes, et al. 2012	PD	N/A	Editorial Piece	Research on driving rehabilitation in people with neurological disorders is still in its infancy. The few studies that have been published so far suffer from methodological issues, which complicate making recommendations based on current evidence. Yet, the results suggest that contextual driving rehabilitation via on-road training or simulator-based driving training may be superior to the training of the underlying cognitive deficit. The identification of the most beneficial driving rehabilitation concept via adequately powered, multicenter randomized controlled trials is a priority on the research agenda for the next decennium.	N/A	This was a review/editorial	N/A

Author	PD or LBD	Number of subjects	Study Design	Main Findings	Limitations	Notes	Quality Rating
5. Bhatia S & Gupta A 2003	PD	N/A	Review	Programs developed particularly for family members caring for PD patients with cognitive loss may be useful for helping them more successfully care for the impaired relative. Education about the nature of cognitive loss, problem-solving, practical problems, and the provision of emotional support are key components of such psychoeducation. Through family training series and conferences, caregivers can learn behavior management techniques and other information to assist them in their role.	N/A	This was a review	N/A
6. Crizzle, Alexander M. & Myers, Anita M. 2013	PD	27 participants 20 controls	Car chip pro electronic data recorder, driving comfort scale	Compared to controls, the PD group drove significantly less overall (number of trips, kilometres, duration), and proportionately less at night and on days with bad weather suggesting more restricted driving practices, congruent with lower ratings of driving comfort and abilities. However, they may not necessarily drive more cautiously or safely as they drove significantly faster (and over the speed limit) on highways and freeways and 19% reported driving problems.	Given the study criteria (driving at least 3 times per week), the study may not have captured drivers with PD who were restricting to a greater extent. Older adults who volunteer for driving studies in general tend to be more educated, active, confident and consider themselves to be good drivers. They may also have fewer impairments or be unaware of their deficits, which may be particularly true for drivers with neurological disorder. In any case, these samples may not be representative of older or PD drivers in general. As this was a cross-sectional study, it was impossible to determine when drivers with PD began restricting their driving practices or whether this was due to declining abilities, or other factors such as no longer driving to work.	Some of the results were presented at the 6th International Driving Symposium on Human Factors in Driving Assessment, Training and Vehicle Design in Lake Tahoe, CA, and the 64th annual meeting of the Gerontological Society of America in Boston, MA. Both Drs Alexander Crizzle and Anita Myers are members of the Canadian Driving Research Initiative for Vehicular Safety in the Elderly (Candrive). Funding for the study was provided by Candrive, the University of Waterloo Schlegel Research Institute of Aging, and the Sun Life Financial Movement Disorders Research and Rehabilitation Centre (MDRC).	6/6
7. Klimkeit, Ester I. 2009	PD	N/A	Review	The reviewed studies indicate that many individuals restrict their driving post-PD diagnosis, suggesting that they are aware that their symptoms are affecting their driving performance. Most individuals with PD decide to cease driving based on their own judgment, or advice from family and/or clinician rather than as a result of a formal driving assessment. This is somewhat concerning given that clinicians including neurologists, may overestimate driving skills of PD patients, and a substantial proportion of drivers tend to overestimate their driving abilities.	While it provides a current overview of the ongoing research, more comprehensive research is required for the full and proper development of policies and guidelines for assessing fitness to drive in PD.	N/A	N/A
8. Crizzle, Alexander M et al., 2013	PD	26 participants 20 controls	Cognitive assessment, Self-reported driving information, objective driving data	Self-estimates of distance driven (km) over the two weeks were inaccurate in both groups; however the tendency to under-estimate was more pronounced in PD drivers. Drivers with PD reported more self-restrictions, yet drove more at night, in bad weather, in rush hour and on highways than they reported. Drivers with PD had significantly lower memory scores overall , however, scores were not correlated with self-reported restrictions, or actual driving distance in either group.	The primary limitation of the study is that there was a small, male dominated sample of well-educated and active drivers.	N/A	5/6 The sample was not representative

Author	PD or LBD	Number of subjects	Study Design	Main Findings	Limitations	Notes	Quality Rating
9. Crizzle AM; Classen S 2012	PD	N/A	Evidence based review	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.	N/A	N/A	N/A
10. Avanzi M, Et al. 2008	PD	N/A	Case control	When L-dopa reduction was feasible, it resulted in cessation of unsafe driving.	Case study methodology	N/A	N/A
11. Amick, M. M., Et al., 2007	PD	21 participants	Clinical evaluation, road test	Twenty-one patients with PD completed the Epworth Sleepiness Scale (ESS) and an on-road driving test. Five participants had EDS according to their self-report on the ESS. Neither EDS nor PD medications were associated with on-road driving performance. These findings suggest that in this pilot study EDS did not impair PD patients' driving skills on a formal driving evaluation.	There is no objective measure of sleepiness, so ESS was used to measure daytime sleepiness. While there are a variety of subjective scales for measuring sleepiness in PD, the ESS was selected for this study because it is the most frequently used measure in the PD and driving literature. Furthermore it can be quickly and easily administered, which makes it an ideal tool for use in the daily care of PD patients. Another limitation was the small sample size.	N/A	5/6 Small sample size
12. Singh R; Pentland B; Hunter J; Provan F 2007	PD	154	Clinical tests, examination, driving assessment	The majority of cases (104, 66%) were able to continue driving although 46 individuals required an automatic transmission and 10 others needed car modifications. Ability to drive was predicted by the severity of physical disease, age, presence of other associated medical conditions, particularly dementia, duration of disease, brake reaction, time on a test rig and score on a driving test. The level of drug treatment and the length of driving history were not correlated. Discriminant analysis revealed that the most important features in distinguishing safety to drive were severe physical disease, reaction time, moderate disease associated with another medical condition and high score on car testing.	Small sample size, study was based on a survey of volunteers	N/A	4/6 inadequate sample size and findings somewhat unclear

Author	PD or LBD	Number of subjects	Study Design	Main Findings	Limitations	Notes	Quality Rating
13. Chee, D. Y. T. 2013	PD	28 participants 30 controls	PC based driving stimulator, computer based driving assessment tool	When compared with healthy controls, PD drivers scored lower in motor and cognitive psychometric assessments and performed less competently in driving assessments. However, PD drivers drove more cautiously and took more time to complete all the driving tests when compared with the healthy counterparts. With the distraction of the secondary task, both the performance of PD drivers and controls declined, but PD drivers to a greater extent. The Trail-Making Test-B was found to be valuable in predicting the overall performance of PD drivers. The ability of PD participants was observed to have significant deterioration in driving through T-junctions and roundabouts.	The participants who volunteered in the current study should not be taken s representatives of the older PD driver's population, since the sample was not randomly selected and only covered certain sectors of the community. Nonetheless, random sampling was neither possible nor practical for this study. Selection bias was thus unavoidable in the recruitment of participants. The sampling bias of self-selected PD participants who volunteered in the study may be 'superior' in the PD population. The relatively small sample size of the study could have also made the 'real' group difference difficult to detect in test scores.	N/A	5/6 insufficient sample that was not representative
14. Horne, J.A. & Reyner, L.A. 2000	PD	N/A	Review	Putative countermeasures to sleepiness, adopted during continued driving (e.g. cold air, use of car radio) are only effective for a short while, even in healthy, sleepy individuals. The only safe countermeasure to driver sleepiness, particularly when the driver reaches the stage of fighting sleep, is to cease driving - and, perhaps, take a 30-min break encompassing a short nap and/or coffee (about 150 mg caffeine).	N/A	N/A	N/A
15. Vaux, Lindsay M Et al., 2010	PD	14 participants 18 controls	Stimuli, cognitive and visual tests	The neurodegenerative disease group was less sensitive in detecting collisions than the comparison group, and sensitivity worsened with increasing number of objects in the display and increasing time to contact of those objects. Poor performance on tests of cognition and visual attention were associated with poor collision detection sensitivity. The results of this study indicate that neurodegenerative disease impairs the ability to accurately detect impending collisions and that these decrements are likely the combined result of visual and cognitive disturbances related to disease status.	Small sample size	N/A	5/6 Insufficient representative sample
16. Uitti, R. 2009	PD	N/A	Review	Patients with Parkinson's disease (PD), therefore, understandably wish to continue to be able to maintain their ability to drive automobiles, motorcycles, airplanes, and boats, etc. The ability to determine if and when a PD patient is no longer fit to drive a motor vehicle is important for maintaining safety for the PD patient and the public. There are numerous requirements for being able to drive a motor vehicle safely. When any of these capacities deteriorate, the ability to drive safely may be lost.	N/A	Funding Mayo Clinic Jacksonville is a Morris K. Udall Parkinson's Disease Research Center of Excellence (NINDS P50 #NS40256) (RJU). RJU is also partially funded by Pacific Alzheimer Research Foundation (PARF) grant C06-01.	N/A

Author	PD or LBD	Number of subjects	Study Design	Main Findings	Limitations	Notes	Quality Rating
17. Stolwyk, R. J. Et al. 2006	PD	18 participants 18 controls	Driving simulator and clinical neuropsychological tests	Results suggest that executive difficulties in people with PD such as working memory, planning and set shifting are associated with reduced tactical level driving performance such as speed adaptation and complex curve navigation. Impaired information processing, visual attention and visual perception in people with PD appears associated with reduced operational level driving performance, such as reacting to road obstacles and maintaining constant lane position. Few correlations were found between measures of physical mobility and psychomotor speed with driving measures.	In this study, a relatively limited sample size was employed. There are three main issues surrounding this limitation when employing correlational analysis, including reduced power (not identifying significant correlations), over-fitting (finding false positive correlations), and obtaining an unrepresentative sample (atypical of the general population).	N/A	5/6 insufficient sample size
18. Radford, Kate A. Lincoln, Nadina B. Lennox, Graham 2004	PD	51 participants	Webster's rating scale of physical ability, Unified Parkinsons Disease rating scale, Stroke Drivers screening assessment, adult memory and information processing battery, Stroop color/word test, serial addition task, tapping task	The unsafe drivers were significantly more disabled, as assessed on Webster's Scale, than those who were found safe to drive. There were no significant differences in the cognitive abilities of safe and unsafe drivers. The most common faults, which caused drivers to be judged unsafe, were lack of observations to the side at junctions, poor positioning on the road and poor driving on roundabouts. There were significant correlations between driving ability and performance on the Cancellation task and the Story Recall and Information Processing.	The study failed to provide a screening measure to differentiate drivers with PD, who are at risk of being unsafe on the road from those who are safe. The sample did not include enough unsafe drivers to conduct a discriminant function analysis to identify whether a combination of physical and cognitive measures could be used to identify drivers in need of further evaluation.	N/A	6/6
19. Amick, M. M., Melissa Grace, J., Ott, B. R. 2007	PD	25 participants	On road driving test, neuropsychological testing	Poorer driving performance was associated with worse performance on measures of visuospatial constructions, set shifting, and attention. While impaired driving was associated with a range of cognitive and visual abilities, only a composite measure of executive functioning and visuospatial abilities, and not attentional skills, predicted driving performance.	Small sample	N/A	5/6 Insufficient sample size
20. Newman NJ 2006	PD	N/A	Review	This study confirms that drivers with Parkinson's disease are significantly less safe than age-matched control drivers. One of the most obvious implications of this and other studies is that drivers with this diagnosis require education regarding their driving capabilities, as well as continuous monitoring for progression of their deficits. It is unrealistic to expect Parkinson's disease patients to fully recognize their limitations in this regard. The question remains whether early identification and application of rehabilitation targeted to those aspects of driving most troublesome for this group of patients would improve their driving performance and prolong their independence, without risking their safety and the safety of others.	N/A	N/A	N/A

Author	PD or LBD	Number of subjects	Study Design	Main Findings	Limitations	Notes	Quality Rating
21. Wood, J. M. et al. 2005	PD	25 participants 21 controls	Automatic dual brake driving test, occupational therapy assessment, driving instructor assessment	The drivers with PD were rated as significantly less safe than controls, and more than half of the drivers with PD would not have passed a state based driving test. The driver safety ratings were more strongly related to disease duration than to their on time Unified Parkinson's Disease Rating Scale. Drivers with PD made significantly more errors than the control group during maneuvers that involved changing lanes and lane keeping, monitoring their blind spot, reversing, car parking, and traffic light controlled intersections. The driving instructor also had to intervene to avoid an incident significantly more often for drivers with PD than for controls. Interestingly, driver safety ratings were unrelated to an individual's rating of their own driving performance, and this was the case for all participants.	Drivers with PD in our study had chosen to continue driving, had retained their license, and had volunteered to participate in our study and are therefore likely to drive better than average, given that many patients with PD choose to stop driving. The current results probably overestimate the driving performance of the wider PD population, and may under-represent the true driving performance decrement that accompanies the disease. In addition, these driving performance scores were obtained during optimal on time medication and do not address the impact of symptom fluctuations in PD.	This study was supported by the Centre for Accident and Road Safety Research, Queensland (CARRS-Q 99039).	6/6
22. Innes, CR 2007	PD	50 participants	Sensory motor tests, cognitive tests, divided attention tasks, complex attention, visual search, decision making, planning	BLR and NCRA correctly classified 94% and 90% of referrals respectively as on-road pass or fail. Leave-one-out cross-validation estimated that BLR and NCRA would correctly predict the classification of 86% and 76% respectively of an independent referral group as on-road pass or fail.	A limitation of the current study is the relatively small number of referrals and the relatively high proportion of stroke patients.	N/A	5/6 insufficient sample
	PD						
	PD						

Table 1: Descriptive Characteristics of Included Studies.

behind the wheel such as distracted driving [10]. Lewy body dementia can also present distorted vision, memory distortions between reality and fantasy, and misidentification of people and objects and as it is known, good vision is required to accomplish safe driving [10].

Parkinson's disease and driving

Of the twenty-one articles reviewed about Parkinson's disease and driving, none of them scored below a 4/6. Eight articles weren't scored because they were review articles and did not contain original data. Overall, the majority of articles lost points because their sample size was too small, not indicative of a generalizable population, or some of the results were not clearly written. There are four themes that emerged from reviewing these articles. The first theme focused on studies that used performance on neuropsychological tests and cognition as predictors of driving abilities in patients with Parkinson's disease. The second theme was driving safety behaviors/driving self-regulation and limitation among people with Parkinson's disease. The third theme was sleep disorders/sleepiness/medication use and driving ability among patients with Parkinson's disease. The final theme that emerged from the studies was the review articles encompassing the overall topic of Parkinson's disease and driving ability.

Neuropsychological testing/cognition

A total of five studies were grouped in this category [12-16]. One overall theme of these studies was that neuropsychological testing is correlated with driving safety errors. Specific cognitive domains included visuospatial ability, memory, and speed of processing.

Lower scores in these cognitive domains predicted more driving safety errors in one study. Further these studies also highlighted that patients with Parkinson's who no longer drive had severe cognitive deficits compared to those with Parkinson's disease that are still driving. Explicitly, ex-drivers with Parkinson's had severe memory impairment, attention deficits, and major impairments in executive functions compared to current drivers with PD. Additionally, these studies highlighted that drivers with Parkinson's performed less competently in motor skill ability and cognitive ability than healthy matched control groups. Overall these studies indicated that cognitive performance is solid predictor of driving ability in patients with Parkinson's. Each study in this group highlighted that drivers with Parkinson's had lower cognitive domain scores in such categories as working memory, planning, and shifting. These abilities are all necessary for driving, thus these articles highlighted that drivers with PD should limit or cease driving when cognitive status begins to decline significantly.

Driving behaviors/driving self-regulation and limitation

Collectively, the studies in this group highlight the driving

limitations and self-regulations that people with Parkinson's disease may impose upon themselves, compared to healthy controls. Overall, there were seven studies in this group [7,14,16-20]. These studies highlighted that drivers with Parkinson's disease tend to drive significantly less overall, drive less in bad weather conditions, and have less confidence and comfort behind the wheel than healthy age matched controls. Further, one study used global positioning tracking devices to track drivers with PD and found that these drivers underestimated the overall amount of driving undertaken, the conditions of driving undertaken, and the time of day of driving undertaken compared to healthy matched controls. This suggests that drivers with PD may have deficits in cognition that impair their ability to remember and recall their actual driving activity. Moreover, another study in this group highlighted that drivers with PD can remain active drivers, but usually need car modifications to continue to drive safely. The articles also highlighted that people with PD were less likely to be able to detect simulated collisions and other driving dangers, highlighting that decrements in vision and cognition are the reason that this may occur. Collectively, the studies also illuminated that patients with PD have trouble navigating roundabouts, engaging in poor positioning on roadways and junctions, changing lanes, monitoring blind spots, reversing, parking, and understanding traffic signals at intersections. Conclusively, these studies highlighted that drivers with Parkinson's are significantly less safe behind the wheel than healthy age matched controls.

Sleep Disorders/sleepiness/medication use

There were three studies on this group overall [20-22]. Two studies focused on sleepiness and sleep disorders associated with Parkinson's disease and driving ability, whereas one article focused on Parkinson's medication use and driving performance. Excessive daytime somnolence is associated with Parkinson's disease, however one study found that excessive daytime sleepiness was not associated with on road driving performance for those drivers with Parkinson's disease. Moreover another study highlighted that sleep attacks often occur in patients with Parkinson's and can occur behind the wheel. This study noted that the best way to counteract sleep attacks in people with Parkinson's is to completely cease all driving behavior at the time of attack, take a short nap, or drink some coffee; instead of using temporary fixes such as blasting cold air or turning on the radio. One study in this group focused on the effects of L-Dopa, a medication used to treat Parkinson's disease and its effect on driving ability. The study highlighted that lowering the dosage of L-Dopa was associated with cessation of unsafe driving in people with Parkinson's disease. Overall the studies on this group underscore that sleepiness and medication use should be monitored in patients with Parkinson's disease that still drive a vehicle.

Review Articles

There were a total of 6 studies included in this group [9,16,19,20,23,24]. These review studies focused on a wide range of topics that cover Parkinson's disease and driving including caregiving issues, current overview of factors effecting driving ability in patients with Parkinson's disease, factors contributing to declines in safety among drivers with Parkinson's disease, factors that affect patients with Parkinson's ability to drive beyond just visual acuity, driving rehab for people with Parkinson's disease, and policy recommendations for clinicians assessing capability to drive in Parkinson's patients. Each review summarized an important piece to the puzzle of driving safety and ability of people with Parkinson's disease. Explicitly, one article highlighted that driving rehabilitation services tailored to patients with neurodegenerative diseases like Parkinson's disease are still in their infancy. Further, another review highlighted caregiving issues and the impact on activities of daily living that people with Parkinson's face. Moreover, three of the reviews described cognitive decline, visual impairment, motor deficits, medication use, disease duration and severity, and excessive daytime sleepiness as predictors of poor driving performance in patients with Parkinson's disease. Lastly one review highlighted the importance of policy implications by suggesting better cooperation among clinicians and more effective screening tools to quell the problem of people with Parkinson's disease that are driving when they shouldn't be.

Discussion

One of the most compelling findings from this study is that there is only one study that was published in the last twenty years about Lewy Body dementia and driving. This topic needs a lot more attention than it is receiving because Lewy Body dementia is second behind Alzheimer's disease as the second most common form of neurodegenerative dementia. The dearth of literature in this area is likely because diagnosis for patients is commonly delayed [25]. Research has also shown that physicians may have limited training in the area of making a diagnosis of Lewy Body dementia or in symptom management that are affiliated with it [25]. Furthermore, doctors and other providers may not be aware of the community resources available to caregivers of those with Lewy body dementia [25].

This gap in the literature needs attention from clinicians and researchers so that people with Lewy Body dementia can regulate and cease driving when the time is appropriate for their disease course. There is no specific scientific literature about Lewy body dementia and licensing, renewal procedures, and mandatory medical reporting systems are not capable of reporting the disease at this time. Some states encourage physicians to report individuals who may be unsafe behind the wheel, but it is voluntary, not mandatory and other states encourage self-reporting as well as family reporting. Moreover, in many cases, a driver that is unfit behind the wheel may have to be reported via mail and that causes delays in processing.

The findings in this study about Parkinson's disease highlight cognitive testing as a major predictor of safe driving. This finding aligns with other reviews and previous work in this area [4,9,26]. Cognition and driving ability has long been studied and it is established that higher cognition levels promote more driving safety. The results of this review support this, highlighting specific cognitive domains that may effect driving performance in people with Parkinson's disease [6,8,22,27]. More study could be directed in this area focusing one single domain such as attention span and its relationship to drivers with Parkinson's disease.

This review also illuminated behaviors drivers limit when they have Parkinson's disease. Because drivers with Parkinson's perform worse on safety in most driving situations, they must limit their driving habits accordingly. Studies have detected what driving behaviors are most committed by people with

Parkinson's disease, but more research to confirm these findings is ideal for future research. Isolating which behaviors are likely to occur in people during simulator tasks and on road tasks may help elucidate and focus the current studies. Limiting driving due to physical disease coupled with Parkinson's is another area that could warrant more research. Some studies discuss ADL impairment and the impact on driving with Parkinson's, but none reviewed here discuss specifics of the impact of physical disease.

This study has its limitations. First, there are many more studies out there that could not fit into this review, so the review is somewhat limited. Further, this study included review articles in the analysis. Some systematic reviews do not include these studies in the final sample. Further, only 6 categories were used to evaluate the quality of the articles reviewed. The Downs and Black evaluation contains 21 items and is more comprehensive, but these studies just did not apply to many of the quality indicators.

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