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Which are the critical parameters assessing the driving performance of drivers with cerebral diseases? A literature review

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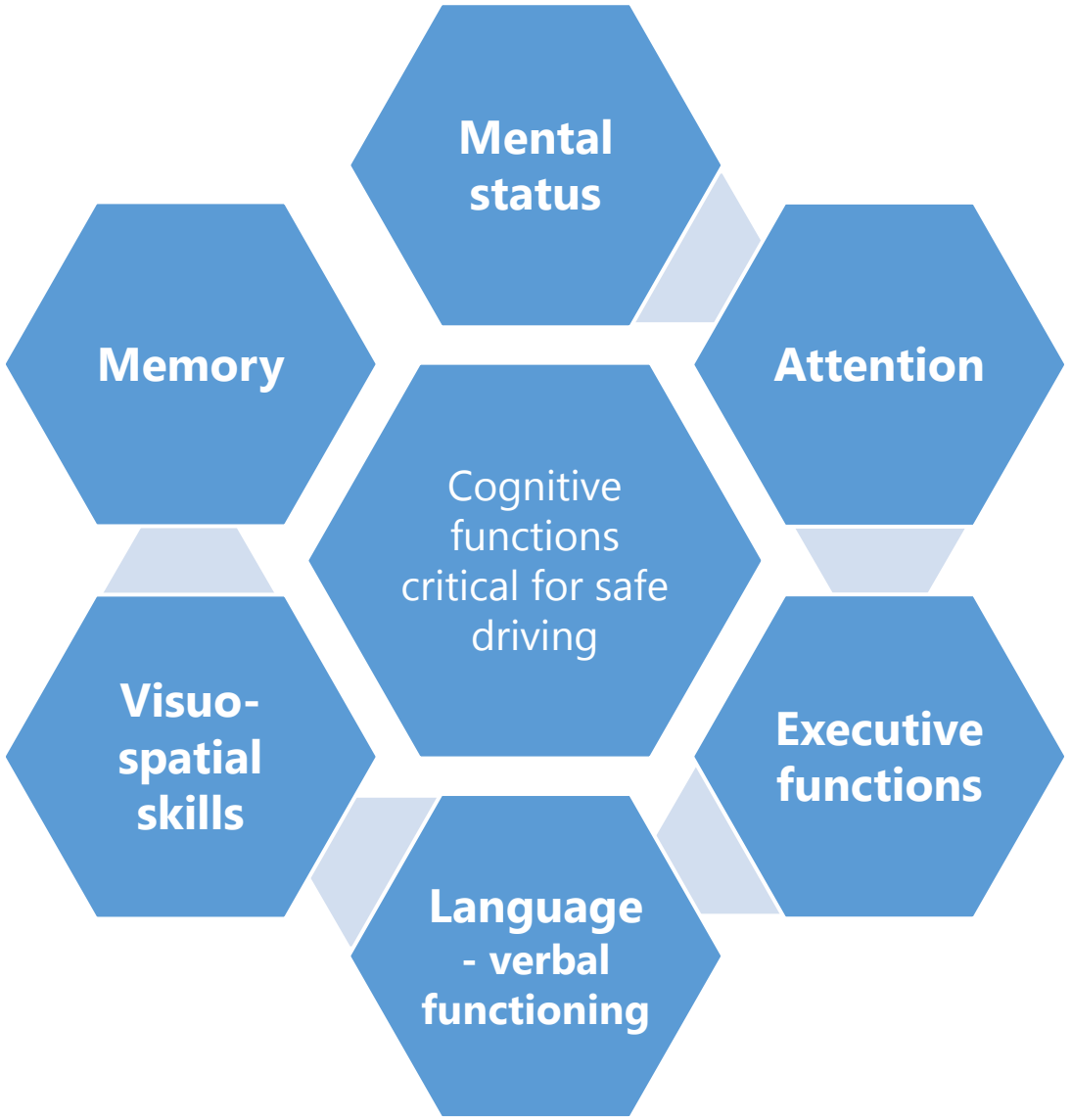
Outline

1. Introduction
2. Objectives - Methodology
3. Drivers with cerebral diseases
4. Driving performance measures of drivers with cerebral diseases
5. Discussion - Conclusions

Cognitive functions critical for safe driving

- The task of driving requires the ability to receive sensory information, process the information, and to make proper, timely judgments and responses (Waller, 1980; Freund et al., 2005).

- Cognitive functions related to driving may be categorized into six neuropsychological domains (Reger et al., 2004).



Cerebral diseases

- **Mild Cognitive Impairment (MCI)** is the cognitive state that lies between normal aging and dementia
- A typical MCI patient is one who has a memory impairment beyond what is felt to be normal for age, but is relatively intact in other cognitive domains
- MCI can evolve as a result of a neurodegenerative process, such as Alzheimer's disease

- **Alzheimer's dementia (AD)** is increasingly being recognized as one of the most important medical and social problems in older people and accounts for 60% to 70% of cases of dementia
- It is a chronic neuro-degenerative disease that usually starts slowly and gets worse over time. The most common early symptom is difficulty in remembering recent events (short-term memory loss)

- **Parkinson's disease (PD)** is a degenerative disease of central nervous system that has an impact mainly on motor function
- Symptoms: tremor, slowness of movement, rigidity, impaired posture and balance
- Thinking and behavioural problems may arise, with dementia commonly occurring in the advanced stages of the disease

Objective

- Identify which are the critical parameters that can assess the driving performance of individuals with cerebral diseases, such as MCI, AD and PD, through a literature review:

- 28 studies examining driving performance of MCI, AD and PD patients are analyzed.
- All these studies concern recent research and report quantitative results

Drivers with MCI - initial approach

- **Driving performance can be affected** by a wide variety of medical conditions, such as dementia (Ott & Daiello, 2010).
- MCI patients may experience **an increased level of driving difficulties** in comparison to their healthy counterparts without, however, being characterized as unsafe drivers (Fritteli et al., 2009; Kawano, et al., 2012; Olsen et al., 2014).
- So far, the literature investigating driving performance in the MCI population **is relatively sparse** (O' Connor et al, 2010).

Driving performance of drivers with MCI

			Diagnosis				Sample Scheme			Type of assessments				Driving Performance Measures with Significant differences							overall worse driving performance	
	Authors	year	MCI	AD	PD	Controls	sample size	age <55	age >55	on road	driving simulator	neurological /neuropsychological examination	questionnaire	driving errors	speed (+variability)	lateral position (+variability)	reaction time	headway	left turns	time to collision		
1	Wadley et al.	2009	●	-	-	●	105 (46+59)	-	●	●	-	●	●			●			●		●	MCI: 5/8
2	Snellgrove	2005	●	-	-	-	115	-	●	●	-	●	-	●	●	●					●	
3	Griffith et al.	2013	●	-	-	●	49 (15+34)	-	●	●	-	●	●	●		●					●	
4	Bowers	2013	●	-	-	-	47	-	●	●	-	●	-	●	●						●	
5	Devlin et al.	2012	●	-	-	●	28 (14+14)	-	●	-	●	●	●	-	-	-	-	-	-	-	-	
6	Kawano et al.	2012	●	-	-	●	57 (12+45)	●	●	-	●	●	●				-	●			○	
7	Fritteli et al.	2009	●	●	-	●	60 (20+20+20)	-	●	-	●	●	●	●			●			●	-	
8	Pavlou et al.	2015	●	●	-	●	75 (23+14+38)	-	●	-	●	●	●		●	●	●	●			●	

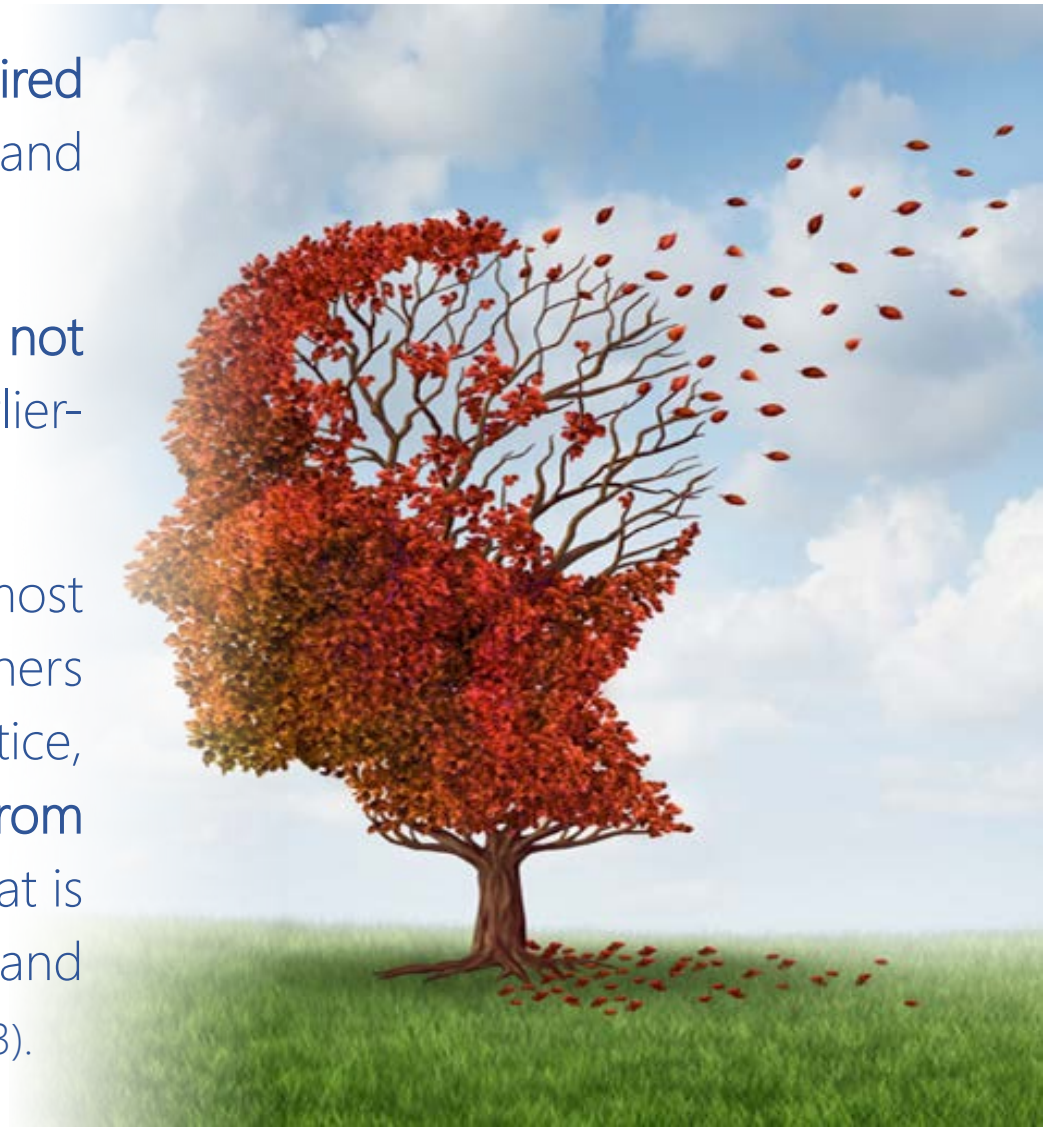
» **Reviewing 8 studies about drivers with MCI**: Studies assessing driving performance through on road testing, indicate that although MCI patients experience subtle changes in their driving competence, they are still able to drive.

» However, a level of impairment compared to healthy controls is generally being reported meaning that **they still constitute a population at risk** that warrants close supervision.

» Studies on simulator environments have demonstrated that individuals with MCI **are deficient in a number of variables** compared to their healthy counterparts.

Drivers with AD - initial approach

- In comparison to healthy controls, AD patients have **an impaired driving ability when tested** with on-road driving experiments and driving simulator assessments (Man-Son-Hing et al., 2007).
- On the other hand, there are some studies which argue that **not all patients with AD are unable to drive**, especially in the earlier-mild stages of the disease (Carr et al., 2000; Perkinson et al., 2005).
- Due to the variance in the progression of symptoms in AD, most neurologists, neuropsychologists or transportation practitioners are faced with the critical question in everyday practice, **regarding the proper time for dissuading AD patients from driving**, as ability to drive is an important factor of daily life that is of critical importance for preserving mobility, independence and self-confidence in the elderly (Gardezi et al., 2006; Johnson et al., 2013).



Driving performance of drivers with AD

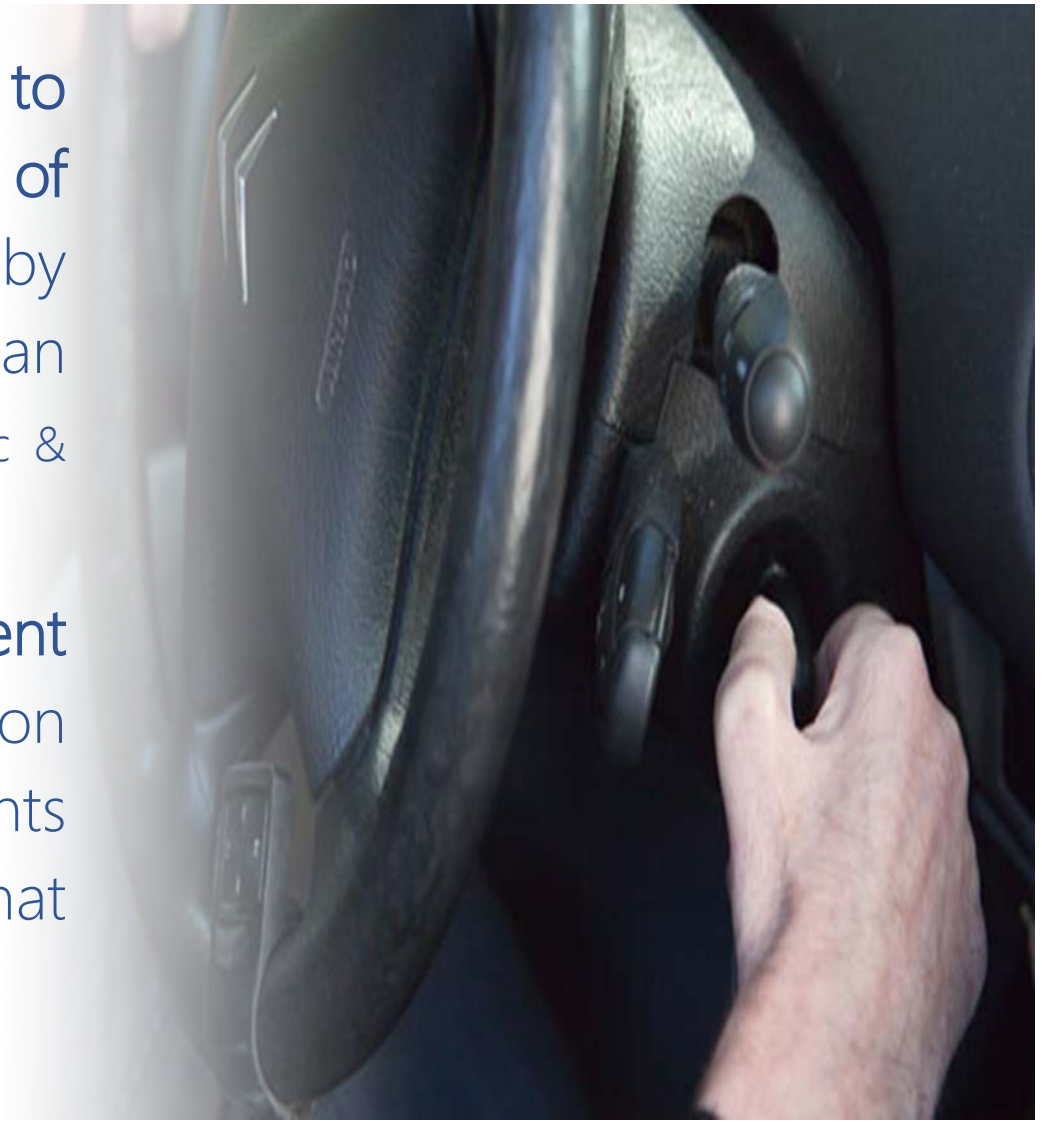
			Diagnosis				Sample Scheme			Type of assessments				Driving Performance Measures with Significant differences										overall worse driving performance	
	Authors	year	MCI	AD	PD	Controls	sample size	age <55	age >55	on road	driving simulator	neurological /neuropsychological examination	questionnaire	driving errors	speed (+variability)	lateral position (+variability)	reaction time	accident risk	headway	left turns	time to collision	confusion or disorientation	seat-belt use		
1	Fritteli et al.	2009	●	●	-	●	60 (20+20+20)	-	●	-	●	●	●	●			●				●			●	AD: 12/13
2	Pavlou et al.	2015	●	●	-	●	75 (23+14+38)	-	●	-	●	●	●		●	●	●		●					●	
3	Hunt et al.	1997	-	●	-	●	123 (65+58)	-	●	●	-	●	-	●										●	
4	Fitten	1995	-	●	-	●	69 (27+42)	●	●	●	-	●	-	●										●	
5	Bieliauskas et al.	1998	-	●	-	●	18 (9+9)	-	●	●	-	●	-	●			●							●	
6	Uc et al.	2004	-	●	-	●	168 (32+134)	-	●	-	●	●	-	●						●		●		●	
7	Ott et al.	2008	-	●	-	●	128 (84+44)	-	●	●	-	●	●					●						●	
8	Dawson et al.	2009	-	●	-	●	165 (40+115)	-	●	-	●	●	●	●										●	
9	Eby et al.	2012	-	●	-	●	43 (17+26)	-	●	●	-	●	●		●							●	●	-	
10	Cox et al.	1998	-	●	-	●	50 (29+21)	-	●	-	●	●	●	●	●					●		●		●	
11	Rizzo et al.	2001	-	●	-	●	30 (18+12)	-	●	-	●	●	-				●	●						●	
12	Uc et al.	2006	-	●	-	●	176 (61+115)	-	●	-	●	●	-		●	●	●	●			●			●	
13	Vaux et al.	2010	-	●	●	●	32 (6+8+18)	-	●	-	●	●	-								●			●	

» Reviewing 13 studies about drivers with AD, driving performance declines considerably in individuals with AD and several on-road and simulator studies indicated worse driving performance for AD group compared to healthy controls in several driving measures.

» Early AD patients may attempt to compensate for their reduced driving skills by limiting the number and length of own driving trips, by driving at reduced speeds but they do a lot of driving errors.

Drivers with PD - initial approach

- The multimodal clinical picture of PD **appears to influence in a negative fashion the performance of various activities of everyday life**, as indicated by research that shows that PD patients have an increased risk to be engaged in car accidents (Uc & Rizzo, 2008; Uitti 2009).
- PD patients found to have **increased accident probability**, which indicates that the association between the level of motor functioning in patients with PD and car accident engagement is an area that warrants further investigation (Dubinsky et al., 1991).



Driving performance of drivers with PD

			Diagnosis				Sample Scheme			Type of assessments				Driving Performance Measures with Significant differences								overall worse driving performance	
	Authors	year	MCI	AD	PD	Controls	sample size	age <55	age >55	on road	driving simulator	neurological /neuropsychological examination	questionnaire	driving errors	speed (+variability)	lateral position (+variability)	reaction time	accident risk	headway	time to collision	significant differences only in neuropsychological tests		
1	Vaux et al.	2010	-	●	●	●	32 (6+8+18)	-	●	-	●	●	-							●		●	
2	Ranchet et al.	2013	-	-	●	●	40 (19+21)	-	●	●	-	●	●		●	●		●	●			●	
3	Heikkila et al.	1998	-	-	●	●	40 (20+20)	-	●	●	-	●	●	●								●	
4	Grace et al.	2005	-	-	●	●	39 (18+21)	-	●	●	-	●	●								●	-	
5	Uc et al.	2006	-	-	●	●	230 (79+151)	-	●	●	-	●	●	●							●	●	PD: 8/10
6	Uc et al.	2009	-	-	●	●	168 (84+182)	-	●	●	-	●	●	●								●	
7	Singh et al.	2007	-	-	●	-	154	-	●	●	-	●	●									○	
8	Lee et al.	2007	-	-	●	●	200 (50+150)	-	●	●	●	●	●	●	●	●		●				●	
9	Classen et al.	2011	-	-	●	●	82 (41+41)	-	●	●	-	●	●	●								●	
10	Pavlou et al.	2015	-	-	●	●	62 (21+41)	-	●	-	●	●	●	●	●	●	●	●	●			●	

» **Reviewing 10 studies about drivers with PD**: driving capacity in patients with PD is mainly compromised due to cognitive deficits.

» **Pronounced difficulties** in several indexes of driving performance appear in drivers with PD under demanding driving conditions that involve increased cognitive load.

» **The use of multiple measures**, apart from driving experiments, that assess various driving domains appears to be essential.

Conclusions - Overview table

	Authors	year	Diagnosis: MCI	AD	PD	Controls	Sample Scheme: sample size	age <55	age >55	Type of assessments: on road	driving simulator	neurological /neuropsychological	questionnaire	Driving Performance Measures with Significant differences: driving errors	speed (+variability)	lateral position (+variability)	reaction time	accident risk	headway	left turns	time to collision	confusion or disorientation	seat-belt use	significant differences only in neuropsychological tests	overall worse driving performance	
1	*Wadley et al.*	2009	●	-	-	●	105 (46+59)	-	●	●	-	●	●			●				●					●	
2	*Snellgrove*	2005	●	-	-	-	115	-	●	●	-	●	-	●	●	●									●	
3	*Griffith et al.*	2013	●	-	-	●	49 (15+34)	-	●	●	-	●	●	●		●									●	
4	*Bowers*	2013	●	-	-	-	47	-	●	●	-	●	-	●	●										●	
5	*Devlin et al.*	2012	●	-	-	●	28 (14+14)	-	●	-	●	●	●	-	-	-	-		-	-	-				●	
6	*Kawano et al.*	2012	●	-	-	●	57 (12+45)	●	●	-	●	●	●				-		●						○	MCI: 5/8
7	*Fritteli et al.*	2009	●	●	-	●	60	-	●	-	●	●	●	●			●				●				●*	
8	*Pavlou et al.*	2015	●	●	-	●	75	-	●	-	●	●	●		●	●	●		●						●	
9	*Hunt et al.*	1997	-	●	-	●	123 (65+58)	-	●	●	-	●	-	●											●	
10	*Fitten*	1995	-	●	-	●	69 (27+42)	●	●	●	-	●	-	●											●	
11	*Bieliauskas et al.*	1998	-	●	-	●	18 (9+9)	-	●	●	-	●	-	●				●							●	
12	*Uc et al.*	2004	-	●	-	●	168	-	●	-	●	●	-	●							●		●		●	
13	*Ott et al.*	2008	-	●	-	●	128 (84+44)	-	●	●	-	●	●						●						●	
14	*Dawson et al.*	2009	-	●	-	●	165	-	●	-	●	●	●	●											●	
15	*Eby et al.*	2012	-	●	-	●	43 (17+26)	-	●	●	-	●	●		●								●	●	-	AD: 12/13
16	*Cox et al.*	1998	-	●	-	●	50 (29+21)	-	●	-	●	●	●	●	●						●		●		●	
17	*Rizzo et al.*	2001	-	●	-	●	30 (18+12)	-	●	-	●	●	-				●	●							●	
18	*Uc et al.*	2006	-	●	-	●	176	-	●	-	●	●	-		●	●	●	●				●			●	
19	*Vaux et al.*	2010	-	●	●	●	32 (6+8+18)	-	●	-	●	●	-									●			●	
20	*Ranchet et al.*	2013	-	-	●	●	40 (19+21)	-	●	●	-	●	●		●	●		●	●						●	
21	*Heikkila et al.*	1998	-	-	●	●	40 (20+20)	-	●	●	-	●	●	●											●	
22	*Grace et al.*	2005	-	-	●	●	39 (18+21)	-	●	●	-	●	●											●	-	
23	*Uc et al.*	2006	-	-	●	●	230	-	●	●	-	●	●	●										●	●	
24	*Uc et al.*	2009	-	-	●	●	168	-	●	●	-	●	●	●											●	
25	*Singh et al.*	2007	-	-	●	-	154	-	●	●	-	●	●					○							○	
26	*Lee et al.*	2007	-	-	●	●	200	-	●	●	●	●	●	●	●	●			●						●	
27	*Classen et al.*	2011	-	-	●	●	82 (41+41)	-	●	●	-	●	●	●											●	
28	*Pavlou et al.*	2015	-	-	●	●	62 (21+41)	-	●	-	●	●	●	●	●	●	●	●	●	●					●	PD: 8/10
*only for the AD group		Total	8	13	10					17	12			16	9	8	6	6	4	3	3	3	1	2		

The main part of this paper included **the review of 28 studies** (some concern more than one cerebral diseases):

- 8 studies about MCI
- 13 about AD
- 10 about PD
- average sample size: 90 participants>55 years old)
- 17 on road
- 12 simulator studies
- In 16 studies drivers with cerebral diseases **committed a lot more driving errors** than controls
- 23/28 studies indicated differences

Conclusions about MCI drivers

- In summary, **the critical driving performance measures** in which drivers with MCI have difficulties are: **driving errors, lateral position, reaction time, speed, headway, left turns and time to collision.**
- Given the small number of existing studies and the concomitant methodological variability, **it is not safe to draw conclusions**, except for the need for systematic monitoring of the MCI population.
- **A strong limitation** of the review regarding the MCI group is that the methodological design of the experiments show considerable variability, in terms of the driving performance measures used, making it difficult to compare the results.
- **A level of driving impairment** is generally reported for the MCI group, which means that they still constitute a population at risk that warrants close supervision.

Conclusions about AD drivers

- In summary, **the critical driving performance measures** in which drivers with AD have difficulties are: **reaction time, driving errors, speed, accident probability, lateral position, headway, left turns, time to collision, confusion or disorientation and use of seat-belt.**
- Several studies clearly demonstrated **driving performance decline** in on-road, as well as simulation experiments in patients with AD. However, as subgroups of these patients have been found to be capable of driving, an accurate prediction of fitness to drive is crucial for patients with AD.
- **Attention, visuospatial skills and executive functions** have been noted as the most critical functions for safe driving, as they appear to affect important driving tasks, such as journey planning, finding one's way, positioning and maneuvering the vehicle, judging distances and predicting the development of driving situations, estimating risk and adapting speed, etc.
- AD patients may attempt to **compensate for their reduced driving skills** by limiting the number and length of their driving trips, by avoiding demanding driving situations and by driving at reduced speeds.

Conclusions about PD drivers

- In summary, **the critical driving performance measures** in which drivers with PD have difficulties are: **driving errors, speed, accident probability, lateral position, reaction time, headway, and time to collision.**
- Drivers with PD are **at risk of driving impairment** because of deterioration of the cognitive functions associated with driving during the course of the disease.
- **Unsafe PD drivers differ** from safe drivers in memory, visuoconstructional, and planning measures, but not on fine motor tasks. Their driving impairment results from a combination of cognitive, visual-perceptual and motor dysfunction.
- Neurological and neuropsychological testing, as well as the progression of the disease, should be viewed as one **part of the screening process that could help** the evaluation of the driving capacity of patients with PD and should not be used alone, because this could lead to imprecise and dangerous consequences.

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