Effects of cerebral diseases on driver distraction

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Abstract

The objective of this paper is to review the literature on the ability of individuals having some kind of cerebral disease to drive, especially while being distracted. Driver distraction, defined as the diversion of attention away from activities critical for safe driving toward a competing activity, is found to be an important cause of road accidents. Driver distraction effects may interfere with several cerebral diseases with high prevalence in the general population, such as Parkinson’s, Alzheimer’s, Mild Dementia and Mild Cognitive Impairment. These diseases affect driver’s attention and other cognitive functions and cause degradation in driving performance, which might in turn translate into increased accident risk, especially at the presence of additional (external) distractors. Overall, the literature review suggests that the interaction between driver distraction and cerebral diseases further downgrades the driving performance. The degree to which these clinical conditions affect driving behaviour and accident risk need further investigation.

Introduction

Driving is a complex activity, requiring several tasks to be performed simultaneously, and attention and perception are key determinants of the driving performance (Duchek et al. 1998). This is not surprising, as many driving situations require the simultaneous processing of numerous pieces of information and the taking of quick decisions.

Older drivers generally exhibit a higher risk of involvement in a road accident (Baldock et al. 2007, OECD 2008). Moreover, diseases affecting a person's brain functioning may significantly impair the person's driving performance, especially for the elderly (Wood et al. 2005, Cordell et al. 2008, Cubo et al. 2009, Frittelli et al. 2009). For example, Mild Cognitive Impairment (MCI), which is considered to be the predementia stage of various types of dementia, is a common clinical condition that may be observed in about 16% of individuals over 64 years old in the general population (Ravaglia et al. 2008). Recent studies suggest that MCI is associated with impaired driving performance to some extent (Frittelli et al. 2009). Deficits related to driving have also been associated with Alzheimer’s disease (Uc et al. 2005; Tomioka al. 2009). Studies regarding Parkinson disease are less conclusive in terms of the impact of its clinical parameters on driving abilities (Cordell et al. 2008, Cubo et al. 2009).

On the other hand, driver distraction constitutes a basic factor for increased risk for road accidents internationally. Although distraction may be considered as a typical part of everyday driving (Stutts et al., 2001), it is reported in the international literature that driver distraction is a contributory factor of road accidents in a proportion ranging from 10-15% to 30% (MacEvoy et al., 2007; Wang et al., 1996). Apart from the various exogenous distraction sources (e.g. mobile phone, in-vehicle information systems, advertising signs etc.), there exist various endogenous – normal or pathological – factors that may affect driver attention or distraction. These factors encompass demographic, personality and behavioural, medical, neurological and neuropsychological factors, and have received notably less attention in the international literature.

Within this context, the objective of this paper is to present a review of studies on cerebral diseases and driver distraction. Eight scientific studies have been identified and examined with respect to the effect of driver distraction on drivers with a cerebral disease, and several others with respect to cerebral diseases and driving in general. This paper is structured as follows: first, the cognitive functions critical for safe driving are specified. Then, an exhaustive literature review of studies on cerebral diseases and driving is presented, and their effects on the critical driving tasks. Then, the distracted driving problem is briefly introduced, followed by an exhaustive review of studies examining the interaction of cerebral diseases and distraction. Conclusions and discussion for further research are drawn from the critical review of the studies.

Cognitive functions critical for safe driving

Driving requires possessing sufficient cognitive, visual and motor skills. The driver must have adequate motor strength, speed and coordination. Perhaps more importantly, higher cognitive skills including concentration, attention, adequate visual perceptual skills, insight and memory need to be present. Higher cortical functions required for driving include strategic and risk taking behavioural skills, including the ability to process multiple simultaneous environmental cues in order to make rapid, accurate and safe decisions. 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).

Congitive functions related to driving may be categorized into the following six neuropsychological domains (Reger et al. 2004):

- mental status-general cognition,
- attention–concentration,
- executive functions,
- language–verbal functioning,
- visuospatial skills,
- memory.

Several researchers (Parasuraman & Nestor 1991; Duchek et al. 1998) have argued that selective attention is most specific to driving deficits in older drivers, or in drivers with some pathological condition (e.g. dementia). Identifying important information in the environment while ignoring irrelevant information may be especially important driving skills. Drivers may compensate for declines in selective attention by driving more slowly, thereby allowing more time for information processing (Hakamies-Blomqvist, 1993). However, safe driving requires that a number of complex decisions are made while selecting attention between concurrent tasks, in a limited time frame.

The importance of visuospatial skills to driving has been noted in several studies (Johansson & Lundberg, 1997; Mitchell et al., 1995). Safe drivers must position the car accurately on the road and manoeuvre the vehicle correctly. Visuospatial skills are also important to judging distances and predicting the development of traffic situations. Visuospatial deficits are commonly observed in older drivers, especially with early dementia, represented by a disturbance in formative activities such as assembling, building, and drawing, so that the individual is unable to assemble parts in order to form a whole (Benton, 1994).

Although attention and visuospatial skills represent a necessary foundation of driving ability, these competencies, like all cognitive skills, require adequate supervision by the executive system of the brain (Royall, 2000). Executive abilities are thought to be important for dual task coordination, and necessary for car positioning, maintaining safe distances, driving on roundabouts, journey planning, estimating risk, and for adapting behaviour such as adjusting speed to traffic conditions (Radford & Lincoln, 2004).

Cerebral diseases and driving

The proportion of elderly people in the general population is rising, resulting in greater numbers of drivers with neurodegenerative disorders such as Dementia, Alzheimer's disease and Parkinson's disease. These neurodegenerative disorders impair cognition, visual perception, and motor function, leading to reduced driver fitness and greater crash risk (Uc & Rizzo 2008).

In Figure 1, the main driving tasks affected by the downgraded cognitive functions of drivers with cerebral disease are presented, according to the results of an exhaustive literature review. These are discussed in detail in the following sections.

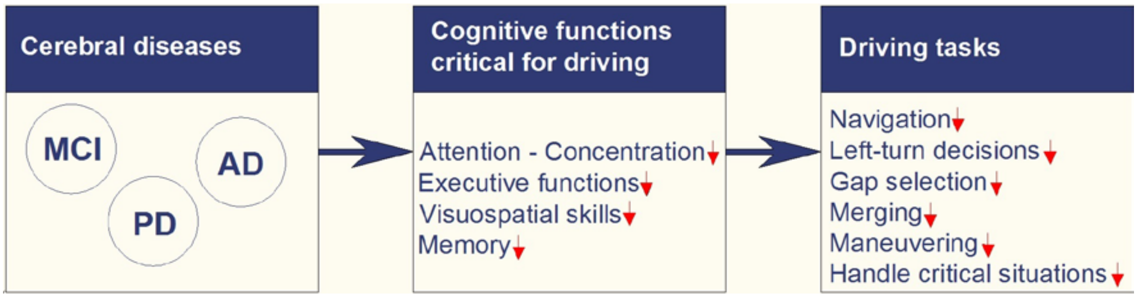

Figure 1 Main cognitive functions and driving tasks affected by cerebral diseases

Dementia

The impact on driving of the cognitive impairments frequently associated with dementia is summarized by Johansson and Lundberg (1997): Dementing diseases bring about impairments of visuospatial skills, attention, memory and judgmen. In reference to dementia, its severity is positively associated with a greater likelihood of poor driving ability (Hunt et al. 1993). While it might be assumed that individuals with dementia would stop driving after onset of symptoms, it is estimated that around one-third of drivers with dementia continue to drive (Silverstein 2008). Most drivers are early in the disease process when cognitive deficits are generally mild (Adler & Kuskowski 2003) and changes to driving performance are minimal. Nonetheless, drivers with dementia are one of the groups considered at greatest risk for unsafe driving performance (Langford et al. 2007).

Road accidents, while infrequent, are also of concern for drivers with dementia, whose crash risk is two to five times that of unimpaired older drivers (Charlton et al. 2003). Furthermore, driving skills predictably worsen (Adler et al. 1999) and will ultimately require individuals with dementia to stop driving (Adler et al. 2005). Driving decisions need to be made not on diagnosis but on an assessment of the dementia’s progress and the disease’s effects on functional abilities (Duchek et al. 2003, Eby et al. 2009a). Unfortunately, there is little consensus on the means to make this assessment (Odenheimer 1993).

MCI and Alzheimer’s disease

Mild cognitive impairment (MCI) is a predementia syndrome involving the onset and evolution of cognitive impairments beyond those expected based on the age and education of the individual, but which are not significant enough to interfere with their daily activities. For the majority of MCI patients, it is found to be a transitional stage between normal aging and dementia. Although MCI can present with a variety of symptoms, when memory loss is the predominant symptom it is termed "amnestic MCI" and is frequently seen as a prodromal stage of Alzheimer's disease. Studies suggest that these individuals tend to progress to probable Alzheimer’s disease at a rate of approximately 10% to 15% per year.

Alzheimer's disease (AD) is the most common form of dementia. In the early stages, the most common symptom is difficulty in remembering recent events. As the disease advances, symptoms can include confusion, irritability, aggression, mood swings, trouble with language, and long-term memory loss (Brookmeyer et al. 2011). The main factors affecting the driving ability and behaviour (accident risk and driving safety) of AD patients are: age, dementia progression degree, education level, mental level, memory (verbal and special), visuospatial perception, structure from motion, attention, and executive functions (impaired judgment) (Uc & Rizzo 2008).

Research results are not conclusive on the extent to which MCI is affecting driving behaviour and safety. MCI drivers seem to have statistically significant driving behaviour deviation (maintaining speed, wheel stability, lateral control) from the control driving population (Wadley et al. 2009). Kawano et al. (2011) tried to ascertain which cognitive features contribute to the safe driving behaviour of MCI drivers. Participants drove using a driving simulator and seemed to have considerable difficulties in maintaining lateral control on a road and in following the vehicle ahead.

Dawson et al. (2009) showed that AD drivers (especially the elderly) made many more safety errors (the most common errors were lane violations). Duchek et al. (2003) provide longitudinal evidence for a decline in driving performance over time, primarily in early-stage dementia of the Alzheimer type Mild AD significantly impaired simulated driving fitness, while MCI limitedly affected driving performance (Frittelli et al. 2009).

Parkinson's disease

Parkinson's disease (PD) is a degenerative disorder of the central nervous system. Early in the course of the disease, the most obvious symptoms are movement-related. Later, thinking and behavioural problems may arise, with dementia commonly occurring in the advanced stages of the disease. Other symptoms include sensory, sleep and emotional problems. The main factors affecting the driving ability and behaviour of PD patients are: age, notability and chronicity of disease, attention, structure from motion, mobility problems (control of the wheel, reaction time), cognitive impairment (visuospatial skills, executive functions), cognitive impairment and dementia (especially decline of visuospatial skills and executive functions), excessive daytime sleepiness, and sudden onset of sleep (Duke Movement Disorders Center, 2011).

Meindorfner et al. (2005) used a questionnaire about sudden onset of sleep (SOS) and driving behaviour to 12.000 PD patients. Of the patients holding a driving license, 15% had been involved in an accident and 11% had caused at least one accident during the past 5 years. The risk of causing accidents was significantly increased for patients who were moderately impaired by PD.

Driver distraction

Human factors in total are the basic causes in 65-95% of road accidents (Sabey & Taylor 1980, Salmon et al. 2011). Driver impairment or distraction factors appear to account for 12% of all road accident contributory factors, while in-vehicle distraction factors account for 2/3 of the total distraction factors (Department for Transport 2008). Driver distraction is therefore estimated to be an important cause of vehicle accidents.

There appears to be a lack of consensus in the literature about what is meant by the terms “driver inattention” and “driver distraction”. Regan et al. (2011) summarise the discussion and suggest that: “Driver Inattention” means insufficient or no attention to activities critical for safe driving and “Driver distraction” is just one form of driver inattention, with the explicit characteristic of the presence of a competing activity.

Driver distraction factors can be subdivided into those that occur outside the vehicle (external) and those that occur inside the vehicle (in-vehicle). Significant factors impacting driving performance and safety have been mostly associated with in-vehicle sources of distraction. These include the use of a mobile phone or a navigation / recreation system, discussing with another passenger, smoking, eating or drinking etc. (Strayer et al. 2003, Johnson et al. 2004, Lesch & Hancock 2004, Neyens & Boyle 2008, Bellinger et al. 2009, Yannis et al. 2010), and have been found to potentially influence both driver behaviour (e.g. in terms of driver speed, lateral position and headways) and road safety (e.g. in terms of reaction times and accident probability).

Several studies suggest that older drivers are more vulnerable to the effects of distracted driving. Simulated driving tasks have shown that older adults have greater difficulty in dividing attention than do younger adults (Brouwer et al. 1991, Ponds et al. 1988). Hancock et al. (2003) showed that the stopping accuracy of older drivers deteriorated statistically significantly more than that of younger drivers when exposed to the distracting effect of mobile phones. In addition, it was shown recently that the presence of passengers was associated with a reduced risk of some unsafe actions (e.g., driving on the wrong side of the road), but an increased risk of other unsafe actions (e.g., ignoring signs).

Review of studies on cerebral diseases and driver distraction

The studies investigating the interaction between cerebral diseases and distraction are limited, because driver distraction is an additional difficulty over the patients' existing difficulties in driving due to the disease. As expected, the majority of the studies, presented below, have shown that distraction of drivers with cerebral diseases has adverse consequences on their behaviour: the impact of distraction on people with cerebral diseases is greater and thus, it is more likely to get involved in an accident for the impaired group while being distracted than the control group.

Driver distraction and MCI or Alzheimer's

Harvey et al. (1995) assessed the performance of patients with dementia on a semi-realistic driving simulator task. The related DRIVAGE project was set up to evaluate the driving abilities of older people, and to examine the potential benefit of providing helpful information to the driver and the burden of adding distracting tasks (Fraser and Warnes 1993, Warnes et al. 1993). The performance of a small group of patients who continued to drive despite a diagnosis of dementia was examined. The results demonstrate that patients with dementia can retain their ability to perform a driving task. Loss of this ability is broadly associated with progression of the dementia, impaired perception and impairment of non-verbal intelligence tests.

Duchek et al. (1998) examined the relationship between visual attention measures and driving performance in healthy older adults and individuals with very mild and mild dementia of the Alzheimer type (DAT). Subjects were administered an on-road driving assessment and three visual attention tasks (visual search, visual monitoring, and useful field of view). The results indicated that error rate and reaction time during visual search were the best predictors of driving performance. Furthermore, visual search performance was predictive of driving performance above and beyond simple dementia severity and several traditional psychometric tests. The results suggest that general cognitive status may be useful for identifying individuals "at risk" for unsafe driving. However, measures of selective attention may serve to better differentiate safe versus unsafe drivers, especially in the DAT population.

Anderson et al. (2007) suggest that memory impairment acquired by experienced drivers does not impair most aspects of driving performance, but may increase safety risk under some challenging circumstances, such as some kind of distraction.

Frank-Garcia et al. (2009) analyzed 64 questionnaires from 38 AD patients, 15 MCI subjects and 11 control volunteers. Among active drivers, MCI patients, unlike controls, showed changes in the driving vehicles (lane departures doubt, distraction with external auditory stimuli, inadequate responses to unexpected situations and increased irritability); no AD patients did drive actually. They concluded that unlike healthy people, MCI patients show changes in driving which could be considered as a possible predictor for future dementia.

Parasuraman et al. (1991) suggests that attentional skills in relation to driving should be examined in older adults with and without dementia of the Alzheimer's type (DAT). Such investigations should focus on normal older adults and those in the mild, early stages of dementia because the latter are the most likely among the dementia population to be still driving. They claimed that motor vehicle accident rates are related to performance on information-processing measures of different components of attention. This relationship is greatest for measures of the switching of selective attention and less for that of divided and sustained attention (vigilance) and that many of these same attentional functions, and particularly the switching of visual selective attention, are impaired in the early stages of DAT and thus may contribute to increased accident risk.

Driver distraction and Parkinson's disease

Uitti (2009) developed a large study (77 patients with mild-moderate PD) utilizing an instrumented vehicle (an actual car driving in real road conditions) concluded that PD drivers took longer to finish the route on a navigation task and made more incorrect turns, got lost, or committed safety errors than controls. PD drivers also had more difficulty identifying specific landmarks and traffic signs. Additionally, they had more errors due to distraction.

Uc et al. (2006) explored the influence of distraction in PD patients during daytime driving on a four-lane freeway under good weather conditions and low traffic load. 71 PD patients and 147 controls underwent a baseline condition and a distraction condition that required while driving the performance of the Paced Auditory Serial Addition Task (PASAT). This particular task is considered to require executive, attentional and working memory resources and aimed to mimic actual conditions of distraction, such as conversation while driving. Compared with controls, drivers with PD committed more errors during both baseline and distraction, and drove slower with higher speed variability during distraction. Although the average effect of distraction on driving performance compared with baseline was not different between the groups, the drivers with PD showed a more heterogeneous response to distraction. The odds of increase in safety errors due to distraction was higher in the PD group even after adjusting for baseline errors, level of engagement in PASAT, sex, and education. Decreased performance on tests of cognitive flexibility, verbal memory, postural control, and increased daytime sleepiness predicted worsening of driving performance due to distraction within the PD group.

Uc et al. (2008) concluded that although both control driving population and PD drivers were similarly affected by the concurrent task on most driving measures, participants with PD were disproportionately affected on operational level driving behaviour, as manifested by closer deceleration points in PD drivers before traffic signals with distraction, despite sacrificing concurrent task performance to maintain driving performance.

Conclusion

According to the review on the interaction between cerebral diseases (MCI, Alzheimer's, Parkinson's etc.) and driver distraction, presented in the previous sections, the majority of the studies indicate downgrade of driving performance and an increase in the likelihood of making a critical mistake in drivers suffering from neurodegenerative diseases. It is noted, however, that the literature on the relationship between driver distraction and brain pathology remains limited and there are several fields of interest for further exploration. Also, it is crucial to have in mind that people with cerebral disease self-regulate (e.g. by slowing down) differently (maybe more) than normal in response to distraction.

As far as MCI or AD patients are concerned, in the early stages of dementia they seem to retain their ability to perform a driving task, but as the disease proceeds, the driving ability deteriorates. There are indications of the cognitive functions that predict this deterioration, but much less is known about the performance of these patients under conditions of distraction.

As far as Parkinson's disease is concerned, the findings do not show a stronger effect of distraction on PD patients than on controls. However, the greater fluctuation of driving errors due to distraction that was observed is a sign that this topic needs further investigation. It is noted however that the related studies are very few and mostly not based on driving simulator experiments

Further research should investigate to which extent drivers with cerebral diseases engage in distracting activities while driving. Maybe, impaired drivers struggle and would adopt coping strategies to manage the routine demands of driving. So, if anything, they would probably engage in less distracting activities than healthy drivers. Distraction may also be viewed as a symptom of the disease (i.e., inability to focus attention on the road or other key elements of driving) rather than a risky behaviour. There are also likely to be age cohort effects whereby the mix of dementia and distraction may not be an issue now, but it will become a greater issue in the future as the multitasking cohort ages.

Finally, various other parameters may be related to the driving performance of individuals with cerebral diseases, including demographic, medical, neurological and neuropsychological parameters. However, these inter-related parameters have not been investigated sufficiently and with a comprehensive methodology. Taking into account that the percentage of the elderly in society is increasing (Baldock et al. 2007), while at the same time the level of motorization also increases (Yannis et al. 2011), the need for the investigation and comparative assessment of the impact of these conditions on driving performance becomes a high priority, especially when they interact with driver distraction parameters.

The analysis of the distracted driving performance of individuals with cerebral diseases could provide countermeasures and useful information for the development of policies that aim at reducing the risk for car accidents and at improving aspects of driving performance e.g. restrictive measures, training and licensing, information campaigns, medical and neuropsychological monitoring etc.

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