



# Comparative assessment of the behaviour of drivers with Mild Cognitive Impairment or Alzheimer's disease in different road and traffic conditions



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## ABSTRACT

The objective of this research was the analysis of the driving performance of drivers with Mild Cognitive Impairment (MCI) or Alzheimer's disease (AD), in different road and traffic conditions, on the basis of a driving simulator experiment. In this experiment, healthy "control" drivers, patients with MCI, and patients with AD, drove at several scenarios at the simulator, after a thorough neurological and neuropsychological assessment. The scenarios include driving in rural and urban areas in low and high traffic volumes. The driving performance of healthy and impaired drivers was analysed and compared by means of Repeated Measures General Linear Modelling techniques. A sample of 75 participants was analysed, out of which 23 were MCI patients and 14 were AD patients. Various driving performance measures were examined, including longitudinal and lateral control measures. The results suggest that the two examined cerebral diseases do affect driving performance, and there were common driving patterns for both cerebral diseases, as well as particular characteristics of specific pathologies. More specifically, cognitively impaired drivers drive at lower speeds and with larger headway compared to healthy drivers. Moreover, they appear to have difficulties in positioning the vehicle on the lane. The group of patients had difficulties in all road and traffic environments, and especially when traffic volume was high. Most importantly, both cerebral diseases appear to significantly impair reaction times at incidents. The results of this research suggest that compensatory behaviours developed by impaired drivers are not adequate to counterbalance the direct effects of these cerebral diseases on driving skills. They also demonstrate that driving impairments increase as cognitive impairments become more severe (from MCI to AD).

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## 1. Background

### 1.1. General

The task of driving requires the ability to receive sensory information, process the information, and make proper, timely judgments and responses (Freund, Gravenstein, Ferris, Burke, & Shaheen, 2005; Waller, 1980). Various motor, visual,

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cognitive and perceptual deficits can affect the ability to drive. These deficits are either age-related or caused by neurological disorders and may lead to reduced driver fitness and increased crash risk. More specifically, diseases affecting a person's brain functioning (e.g. the presence of specific brain pathology due to neurological diseases as Alzheimer's disease) may have obvious impacts on driving performance (Cordell, Lee, et al., 2008; Cubo, Martinez Martin, et al., 2009; Frittelli et al., 2009; Wood, Worringham, et al., 2005), but in mild cases and importantly in the early stages, they may be imperceptible in one's daily routine. Furthermore, the neuropsychological parameters associated with driving performance deficits of cognitively impaired individuals are reaction time, visual attention, speed of perception and processing, and general cognitive and executive functions. These parameters show considerable decline with age or at the presence of cognitive impairments and have been associated with the probability of accident involvement (Lunsman et al., 2008).

On the other hand, driving is an everyday activity of particular importance for older individuals, as it enhances their mobility, self-esteem and social participation (Burkhardt, 1999; Hakamies-Blomqvist & Wahlström, 1998). Given that the percentage of the elderly in society is increasing (Baldock, Mathias, McLean, & Berndt, 2007), and that the level of motorization also increases (Yannis, Antoniou, Papadimitriou, & Katsohis, 2011), the investigation of the impact of these medical conditions on driver performance in different road and traffic environments becomes critical. However, relatively few studies exist analysing the effect of these cerebral diseases on driving performance, and even fewer studies comparing the different cerebral diseases in different conditions.

### 1.2. Mild Cognitive Impairment

Relatively little is known about the competence of drivers with Mild Cognitive Impairment (MCI). This constitutes a considerable gap, given that MCI is a pathological condition with high prevalence in the general population, as ~15% of people >65 years old are affected. In addition, MCI eventually develops into dementia with a high annual rate (Winblad et al., 2004). The concept of MCI has been described as a cognitive state that lies between normal ageing and dementia (Petersen et al., 1995). MCI patients exhibit cognitive decline beyond what is expected to be normal for age, but are otherwise functioning well and do not meet criteria for dementia.

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, following the vehicle ahead, and lateral control) from the control driving population (Kawano et al., 2012; Wadley et al., 2009), may be more vulnerable to complex driving environments and more affected by in-vehicle or external distraction (Cuenen et al., 2015), may conduct more driving errors and unintentional traffic violations, etc. (Papadimitriou et al., 2014). However, drivers with cognitive impairments are often capable of self-regulating to some extent, and their driving impairments are partly balanced by the reduced exposure (driving), especially in demanding conditions (e.g. avoidance of motorways, nighttime driving) and the lower speeds (Breker et al., 2003).

### 1.3. Alzheimer's disease

Alzheimer's disease (AD) is a chronic neurodegenerative disease that has stages; the Clinical Dementia Rating (Morris, 1993) is a five-point scale in which CDR-0 connotes no cognitive impairment, and then the remaining four points are for various stages of dementia: 0.5-very mild dementia (MCI), 1-mild (AD), 2-moderate, and 3-severe; AD usually starts slowly and gets worse over time (Burns & Iliffe, 2009). In the early stages of the disease, a variety of symptoms can be observed with gradually progressive memory impairment being the most prominent symptom. Additional deficits may be present, including visuospatial deficits, impaired attention, executive dysfunction and judgment, verbal fluency and confrontation naming (Zec, 1993).

In particular as regards driving, research showed that AD drivers (especially the elderly) make many more safety errors (the most common errors were lane violations) (Dawson, Anderson, Uc, Dastrup, & Rizzo, 2009). In their review, Man-Son-Hing, Marshall, Molnar, and Wilson (2007) indicated that, in comparison with healthy controls, AD patients have an impaired driving ability when tested with on-road driving experiments and driving simulator assessments. Several other studies indicate driving difficulties in several driving performance measures between AD patients and cognitively intact individuals (Bieliauskas, Roper, Trobe, Green, & Lacy, 1998; Cox, Quillian, & Thorndike, 1998; Dawson et al., 2009; Fitten et al., 1995; Frittelli et al., 2009; Hunt, Murphy, Carr, et al., 1997; Ott et al., 2008; Uc, Rizzo, Anderson, Shi, & Dawson, 2004; Uc, Rizzo, Anderson, Shi, & Dawson, 2006). 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, Duchek, & Morris, 2000; Perkinson et al., 2005). Only a few studies compare mild with more severe dementing diseases with respect to driving. Longitudinal evidence was provided for a decline in driving performance over time, primarily in early-stage dementia of the Alzheimer type (Duchek et al., 2003). In Frittelli et al. (2009), Mild AD significantly impaired simulated driving fitness, while MCI limitedly affected driving performance.

The degree to which these impairments affect driving, and the self-regulating strategies are effective, are critical issues for further research, especially as regards the major question of older and cognitively impaired driver's licensing schemes, the potential restrictions and the eventual withdrawal from driving. So far, in Greece and in many other countries, a strict framework regarding the privilege of driving and the driving licence renewal procedures of patients with cerebral diseases is lacking, and this is of critical importance, as previous studies suggest that patients with dementia at a moderate or severe stage

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