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Mild Cognitive Impairment and driving: Does in-vehicle distraction affect driving performance?

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ABSTRACT

Objectives: In-vehicle distraction is considered to be an important cause of road accidents. Drivers with Mild Cognitive Impairment (MCI), because of their attenuated cognitive resources, may be vulnerable to the effects of distraction; however, previous relevant research is lacking. The main objective of the current study was to explore the effect of in-vehicle distraction on the driving performance of MCI patients, by assessing their reaction time at unexpected incidents and accident probability.
Methods: Thirteen patients with MCI (age: 64.5 ± 7.2) and 12 cognitively intact individuals (age: 60.0 ± 7.7), all active drivers were introduced in the study. The driving simulator experiment included three distraction conditions: (a) undistracted driving, (b) conversing with passenger and (c) conversing through a hand-held mobile phone.
Results: The mixed ANOVA models revealed a greater effect of distraction on MCI patients. Specifically, the use of mobile phone induced a more pronounced impact on reaction time and accident probability in the group of patients, as compared to healthy controls. On the other hand, in the driving condition "conversing with passenger" the interaction effects regarding reaction time and accident probability were not significant. Notably, the aforementioned findings concerning the MCI patients in the case of the mobile phone were observed despite the effort of the drivers to apply a compensatory strategy by reducing significantly their speed in this driving condition.
Conclusion: Overall, the current findings indicate, for the first time, that a common driving practice, such as the use of mobile phone, may have a detrimental impact on the driving performance of individuals with MCI.

1. Introduction

1.1. Mild Cognitive Impairment and driving

The concept of Mild Cognitive Impairment (MCI) has been considered and described as a cognitive state that lies between normal aging and dementia (Petersen et al., 1995). Patients with MCI exhibit cognitive decline beyond what is expected to be normal, according to neuropsychological norms, but their functionality is well-preserved and do not meet the required criteria for dementia. The most common type of MCI, defined as amnestic MCI, refers to a case in which episodic memory impairments predominate but general cognitive functioning remains intact (Petersen et al., 2001; Petersen, 2004).

MCI has been associated with various underlying etiologies (Reisberg et al., 2008). In particular, MCI may evolve as a result of a neurodegenerative process, such as Alzheimer's disease (AD); most of the subjects with memory loss (amnestic MCI) will progress to AD at a rate of 10–15% per year (Petersen, 2004). Also, another possible cause for the appearance of MCI is the presence of cerebrovascular pathology due to small vessel disease (executive or multi-domain) (Petersen, 2004).

Along with other common cerebral disorders affecting cognition, the association between MCI and driving behavior has been explored by several lines of previous research because of the strong link that exists between driving and cognitive functioning. As Reger et al. (2004) have suggested, the main cognitive functions critical for safe driving according to their meta-analysis that focused on patients with dementia are the following: attention (quick perception of the environment), execu-

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tive functions (make rapid and accurate decisions), visuospatial skills (i.e. judging distances, maneuvering the vehicle correctly) and memory (journey planning, adapting behavior, sign recognition). Regarding the patients with MCI, a very recent meta-analysis concluded that measures engaging executive and attentional resources as well as measures of visuospatial ability and global cognition appear to be interwoven with the driving performance of drivers belonging to the specific clinical group (Hird et al., 2016).

According to previous studies that have applied driving simulator evaluations, individuals with MCI as compared to cognitively intact individuals appear to differ only on a portion of the assessed driving indexes. For example, it has been reported that drivers with MCI have significantly shorter mean time to collision and attenuated car following skills, but absence of significant differences in other driving measures, such as number of off-road events, number of infractions and number of stops at traffic lights (Frittelli et al., 2009; Kawano et al., 2012). Another driving simulator study (Devlin et al., 2012) reported only trends but not significant differences regarding the readiness of patients with MCI to stop at intersections. According to the findings of on-road studies, MCI patients were found to be significantly different from the control group in measures of left hand turns, lane control and overall global rating of driving performance but not in right-hand turns, gap judgments, maintaining proper speed and steering steadiness (Wadley et al., 2009). Also, they presented increased rates of less than optimal driving performance in a variety of driving variables, namely lane control, gap judgments, steer steadiness, maintaining speed and overall performance (Griffith et al., 2013). Finally, based on the conclusions of a recent meta-analysis, it appears that drivers with MCI have greater chances of failing an on-road driving test as compared to cognitively healthy older drivers, but on the same time it is indicated that the majority of individuals belonging to the specific clinical group maintain sufficient driving fitness (Hird et al., 2016).

1.2. Driver distraction

Driver distraction constitutes a particular human factor of road accident causation. Driver distraction is generally defined as "a diversion of attention from driving, because the driver is temporarily focusing on an object, person, task or event not related to driving, which reduces the driver's awareness, decision making ability and/or performance, leading to an increased risk of corrective actions, near-crashes, or crashes" (Regan et al., 2011). More specifically, driver distraction involves a secondary task, distracting driver attention from the primary driving task (Donmez et al., 2006; Sheridan, 2004) and may include four different types: physical distraction, visual distraction, auditory distraction and cognitive distraction (Breen, 2009; SWOV, 2016).

Driver distraction factors can be subdivided into those that occur outside the vehicle (external) and those that occur inside the vehicle (in-vehicle). Driver distraction factors that occur inside the vehicle seem to have greater effect on driver behavior and safety. Horberry et al. (2006) confirm that in-vehicle distraction sources have a more important effect on driver performance, compared to the increased complexity of the stimuli received from the road and traffic environment. Moreover, certain studies report that external distraction factors are less than 30% of the total distraction factors (Kircher, 2007; Stutts et al., 2005). Other studies specify that external distraction factors account for less than 10% of all distraction factors (Sagberg, 2001).

According to accumulating evidence, one of the most important in-vehicle distractors appears to be the use of mobile phone (Burns et al., 2002; Dragutinovits and Twisk, 2005; McEvoy et al., 2005; Sagberg, 2001). Patel et al. (2008) by assessing 14 common types of driver distraction, concluded that the highest perceived risk appeared in the case of mobile phone use, whereas "conversing to passengers" was considered as one of the distractors with the lowest perceived risk. Also, the greater distraction load of the mobile phone use, as compared to the conversation with passengers, was documented by NHTSA (2008). In particular, the use of mobile phone was associated with more than 3 times increased accident risk compared to "conversing with a passenger".

The aforementioned pattern of findings may be explained by previous research indicating that the mobile phone use is a high-demand distraction task that can engage all four types of distraction (Breen, 2009; SWOV, 2016). In particular, physical distraction appears when using one or both hands to manipulate the phone, visual distraction is present in cases where the gaze of the driver alternates between the road and the mobile phone's screen, auditory distraction may emerge by the initial ringing of the phone or by the actual conversation, and finally cognitive distraction occurs because the driver allocates concurrently cognitive resources in the tasks of driving and of conversation (Young et al., 2003; Dragutinovits and Twisk, 2005; SWOV, 2016).

Previous research has examined the influence of driver demographics like age and gender on driving performance under driving conditions with distraction. A greater negative impact on the reaction time of older drivers compared to young drivers that used a mobile phone was reported by Caird et al. (2008). Along the same vein, a driving simulator experiment conducted by Nilsson and Alm (1991) showed that elderly drivers' reaction time to an unexpected event was significantly larger than that of young drivers when distracted by a mobile phone conversation. Within the group of older drivers, measures of cognitive functioning that engage attentional resources appear to moderate the link between distraction and driving performance (Cuenen et al., 2015). Also, a study that focused on patients with AD, detected that the presence of difficulties on performing accurate judgments under conditions of distraction could effectively predict the deterioration of the on-road driving skills of the specific group of drivers (Ott and Daiello, 2010).

However, to the best of our knowledge previous research has not focused on the role of distraction on the driving behavior of patients with MCI, a common clinical condition with a high prevalence in the group of older drivers (Zanetti et al., 2006).

2. Objectives

The goal of the present study was to explore the role of in-vehicle distraction on critical road safety measures, namely reaction time at unexpected incidents and accident probability, in drivers with MCI, by applying a driving simulator experiment. The in-vehicle distractors that were applied included a low-demand distraction task, namely conversation with a passenger, as well as a high-demand distraction task, namely the use of hand-held mobile phone while driving. Our underlying rationale was that the decreased cognitive resources of individuals with MCI could possibly accelerate the negative impact of distraction on their driving performance. Notably, patients with MCI appear to be commonly affected in divided attention procedures (Okonkwo et al., 2008) and, therefore, a driving condition including in-vehicle distraction could prove to be a really hard task for drivers with MCI.

In particular, we hypothesized that the high-demanding distractor would have an augmented negative effect on the reaction time and the accident risk of patients with MCI as compared to cognitive intact individuals of similar age, education and driving experience. For the driving condition with the low-demanding distraction task we expected a heightened effect of distraction on the driving performance of MCI patients but of a lesser extent than the one observed under the high-demanding distraction task. For the condition without distraction, by integrating the findings of previous driving simulator studies that indicate that drivers with MCI might differ in a variety of driving indexes from healthy controls, we recognized the likelihood that the two groups could differ also in this case on the measures of reaction time and accident risk, but at a smaller extent as compared to the two distraction conditions and especially to the highly demanding task of