Self-awareness of driving ability in healthy elderly and patients with Mild Cognitive Impairment (MCI)

Abstract

Background: Mental and physical changes that accompany natural ageing are expected to affect driving ability in the elderly. Most elderly drivers, especially under the influence of cognitive impairment, have been found to adjust their driving behavior to compensate for their attenuated skills (Braitman et al., 2011). However, there seems to be a percentage of cognitively impaired drivers that fails to recognize their areas of weakness and overestimate their driving abilities (Wong et al., 2012). **Aim:** The aim of the present study was to evaluate the level of agreement between self-estimated and actual performance on a driving simulator experiment in a group of patients with Mild Cognitive Impairment (MCI) and healthy elderly through a driving simulator experiment. **Methods:** Twenty-seven individuals with amnestic MCI (age: M=66.59 years±8.2) and 26 healthy elderly drivers (age: M=63.01 years±7.8) participated in the study. The data obtained by the simulator included, among others, the following: (a) average speed, (b) headway distance, (c) lateral position, (d) reaction time and (e) steer wheel variation in two driving environments, namely urban and rural. After the driving assessment, participants were asked to self-evaluate their performance in comparison to what they considered as average for people of similar age and educational level. **Results:** According to the applied mixed ANOVA model, the MCI patients presented increased difficulties in estimating their driving performance in the rural environment as compared to the control group. On the contrary, at the urban environment, the two groups did not differ significantly in the accuracy of their subjective driving evaluations. **Discussion:** This is the first study to compare self-assessment of driving performance with direct measures of driving behavior. Our findings suggest that the ability of MCI patients to evaluate their driving performance accurately seems to be enhanced or compromised depending on the number of cues provided by their environment. This pattern of findings is in line with previous research suggesting that the use of cues may improve the metacognitive abilities (Eva & Regher, 2005) and, therefore, it provides a promising base for the design and implementation of effective intervention programs in the MCI population.

Introduction

Healthy elderly and self-regulation of driving

Natural ageing is usually accompanied by several changes in mental and physical capacities. Those changes are thought to affect, at a smaller or larger extent, the ability to perform flawlessly daily tasks. Driving is considered to be a complex activity which requires multiple cognitive and physical skills to be executed successfully.

Several factors which have been associated with safe driving, such as intact vision, motor skills, and cognition may be affected in the elderly population (Vance et al., 2006; Aksan et al., 2012) resulting in elevated crash risk (Rubin et al., 2007; Ross et al., 2009).Due to those changes, elderly drivers may experience enhanced difficulties when faced with more complex driving situations, like driving at night or high traffic. Thus, they commonly adopt several compensatory strategies to counterbalance those difficulties (Dobbs et al., 2001). Those strategies may include the avoidance of more demanding driving situations, driving at lower speeds, maintaining larger distances from the headway vehicle or driving along with a passenger. (Charlton et al., 2003; Donorfio et al., 2008, Braitman et al., 2011; Lyman et al., 2001; Baldock et al., 2006; Holland, 2001).

However, the ability to monitor and evaluate driving performance, recognize areas of weakness and make accurate judgments about the consequences of those deficits on a day to day basis presupposes a certain degree of intact self-awareness to be present (Coleman Bryer et al., 2006; Baldock et al., 2006; Myers et al., 2008; Rudman et al., 2006).Self-awareness is considered to be a critical factor for safe driving as it is one of the key elements that will determine whether elderly drivers will adopt behaviors that will match their attenuated driving skills (Cabeza et al., 2005).

Self-estimation of driving behavior in the literature has been mostly examined through questionnaires. The responses of the participants are consequently compared to objective ratings of driving performance under a pass/fail aptitude to drive result. (Wild & Cotrell, 2003; Freund et al., 2005; Festa et al., 2012)

To our knowledge, a detailed comparison of self-assessment of driving performance across various driving indexes with direct measures of driving ability has been investigated in the literature neither in healthy drivers nor drivers with cognitive impairment.

MCI and driving performance

MCI represents a transitional stage between normal aging and dementia with none or only minimal impairment in everyday activities (Petersen et al., 2004).

Even though preserved daily functioning is a prerequisite for classifying an individual as MCI instead of mild dementia (Petersen et al., 2004), studies exploring functional abilities in the MCI population may detect mild changes in daily activities of the particular group, especially in more complex tasks (e.g. managing finances) that require greater cognitive demands (Weston et al., 2011; Allaire et al., 2009; Albert et al., 2011).

According to the current literature, patients with mild impairments remain generally fit to drive (Devlin et al., 2012; Fritteli et al., 2009; Hird et al., 2016). However, a trend for more driving errors in comparison to cognitively intact individuals of similar age has been noticed, raising the notion that a mild functional decline may have also occurred along with cognition (Fritteli et al., 2009; Wadley et al., 2009; Papageorgiou et al., 2016).For example, according to a recent review conducted by our research team, the most commonly reported driving errors in MCI patients were difficulties with the positioning of the vehicle on the lane and maintaining proper speed, pedal confusion and difficulties with left and right-hand turns (Papageorgiou et al., 2016). Such findings underline the necessity for a thorough investigation of the particular clinical group.

MCI and self-assessment of driving performance

In comparison to studies examining self-awareness of cognitive abilities in the AD population, the exploration of self-evaluation patterns of cognitive abilities in the MCI has been rather recently introduced as an interesting field of research. Although safe conclusions regarding the integrity of self-monitoring abilities in MCI patients are yet to be drawn, several researchers agree that impaired self-awareness can be observed at a respected number of patients (Spalletta et al., 2014; Galeone et al., 2011; Roberts et al., 2009; Fragkiadaki et al., 2016).

So far, few studies have examined the metacognitive abilities as regards driving habits in individuals with mild cognitive impairments. For that reason, the percentage of impaired drivers who do evaluate their driving as deficient and regulate their behavior accordingly in comparison to those who do not change their driving habits remains unclear (Anstey et al., 2000; O'Connor et al., 2010; Sullivan et al., 2011).

From a recent review on exploring regulatory driving behavior in cognitively impaired drivers, the results suggested that the particular group does engage in self-regulatory strategies when experiencing increased difficulties (Devlin et al., 2014). According to several studies, greater levels of cognitive impairment were associated with increased number of self-imposed driving regulations (Kowalski 2012; Meng &

Siren 2012; Baldock et al., 2006; Vance et al., 2006; Okonkwo et al., 2009; Ackerman et al., 2011). However, it is not clear whether these restrictions are a result of self-observation and acknowledgment of attenuated driving skills or whether they are encouraged by their outer environment (Devlin et al., 2014.)

According to other researchers, a certain number of drivers with cognitive impairment continue to drive without making the required adjustments(Wong et al., 2012; Baldock et al., 2006) or may even overestimate their ability, posing a significant risk to personal and public safety (Wild & Cotrell., 2003). Other studies also highlighted that impaired self-awareness of driving ability was associated with the level of cognitive impairment (Farias et al., 2005) and was related to failure on the road (Kay et al., 2009).

The objective of this study was the exploration of self-evaluation patterns regarding driving behavior in individuals with MCI. According to previous research examining self-awareness of cognitive ability in the specific clinical population (Fragkiadaki et al., 2016), we hypothesized that a certain degree of impaired self-awareness would also be present in their self-evaluation patterns of driving ability. What is more, we sought to examine whether the level of feedback and familiarity provided by the task at hand would benefit the self-evaluation abilities of the participants, Thus, we assessed driving ability under two different driving conditions, one in an urban environment which was thought to be more familiar to the participants as permanent habitants of a capital city, and one in a rural environment, which was considered to be a less familiar environment. The urban condition was considered to be a more structured and organized environment offering a greater amount of cues regarding aspects of driving in comparison to the rural environment. Hence, based on previous studies examining metacognitive processes in the healthy population which have underlined the necessity of providing cues in order to enhance the ability to subjectively evaluate a specific performance (Eva & Regher, 2005), we hypothesized that the more organized environment provided by the urban condition would benefit the self-evaluation capacities of the participants.

Methods

The current research was carried out within the framework of the DriverBrain research project entitled “Analysis of performance of drivers with cerebral diseases” conducted by the Cognitive Disorders/Dementia Unit at the 2nd Department of

Neurology of the National and Kapodistrian University of Athens in collaboration with the Department of Transportation Planning and Engineering of the National and Technical University of Athens. The particular project investigated driving skills of patients with neurodegenerative disorders, including Alzheimer's disease, Parkinson's disease and Mild Cognitive Impairment in association with neurological and neuropsychological parameters.

Participants

Participants were recruited from the Cognitive Disorders/Dementia Unit at the 2nd Department of Neurology at NKUA "Attikon" University General Hospital in Athens. In the current study, 27 individuals with amnestic MCI and 26 cognitively intact individuals were included. For the diagnosis of amnestic MCI, the Petersen criteria were applied (2004) requiring: (a) subjective memory complaints also confirmed by an informant, (b) objectively verified memory impairments (c) preserved general cognitive function (d) intact activities of daily living and (e) absence of dementia. Finally, it should be noted that patients with cognitive impairments due to secondary causes (e.g. metabolic disorders, tumors) were excluded from the study.

Inclusion criteria

Inclusion criteria for participating in the study involved the following: (a) a valid driving license, (b) regular driving, (c) no history of psychiatric or other neurological disorder, (d) absence of current psychiatric condition, (e) absence of alcohol or other drug abuse (f) absence of any serious motor or vision impairment.

Procedure

The present study was approved by the ethics committee of "Attikon" University General Hospital. At the initial visit, each participant signed an informed consent which described the nature of the study as well as the procedure that would be followed. The research procedure was divided into two parts. **Part A:** The first part included a thorough medical, neurological and neuropsychological assessment to investigate probable neurological, neuropsychiatric or cognitive impairments. Medical assessment involved the collection of a detailed medical history, a standardized neurological examination, the administration of specialized scales for the assessment of motor coordination and balance as well as evaluation of neuropsychiatric symptoms and functionality of each patient. The neuropsychological battery assessed a broad array of cognitive domains, including episodic memory, executive functions, visual attention and speed of processing, visuospatial perception and psychomotor speed (more details on the neuropsychological examination procedure can be found in Fragkiadaki et al., 2016). **Part B:** At the second phase, the participants underwent a Driving Simulator experiment. The simulator, a FoerstDriving Simulator FPF®, was located at the Department of Transportation Planning and Engineering at the National Technical University of Athens. It consisted of 3 LCD wide screens 40'' (full HD), total angle view of 170 degrees, driving position and support base. The driving assessment included an initial driving practice (10-15 minutes) to enhance familiarization with operating the simulator, as well as two driving trials of approximately 15 minutes each in a rural and an urban environment. The driving assessment included driving at high traffic volume (600 vehicles/hour) without any distraction. During each trial, two unexpected incidents occurred (a donkey crossing the road in the rural environment and a boy chasing a ball or the sudden appearance of a car in the urban environment) to examine the ability of the participants to respond effectively to sudden events.

For the purpose of this study, the driving variables extracted by the simulator were the following: (a) *average speed* (the average actual speed of the vehicle in kilometers per hour), (b) *headway distance* (the distance to ahead driving vehicle in meters), (c) *lateral position* (the average distance to the right road board in meters), (d) *reaction time*(the time between obstacle's first move towards the road and the breaking time in milliseconds) and (c) *steer wheel variation* (the standard deviation of steering wheel position in degrees).

Those variables were selected in order to represent a broad range of driving characteristics incorporating longitudinal parameters (average speed and headway distance), lateral parameters (lateral position and steer wheel variation) and parameters regarding driving readiness and safety (reaction time).

Driving self-awareness evaluation

After the driving simulator assessment, participants were asked to self-evaluate their performance by comparing it to what they considered as average for people of their own age and educational level. The self-evaluation was reported on a scale ranging from -100% to +100% (with 10-point intervals expressed as percentages) for each of the aforementioned driving variables. If the participant believed that their driving represented the average performance, they were encouraged to mark the number zero (0). If they believed that their driving at the simulator differentiated from the average performance at a certain level, they marked a score between -10% and -100% or between +10% and +100%, depending on how much they estimated that their performance was different (as a percentage) from that of an average individual of the same age and educational level. It was also explained to the participants that: (a) in regards to average speed, the values between -10 and -100 represented driving slower than the average driver while the values between +10 and +100 represented driving faster than the average driver (b) in regards to lateral position, the values between -10 and -100 represented driving more on the left side of the road than the average driver while the values between +10 and +100 represented driving more on the right side of the road than the average driver, (c) in regards to headway distance the values between -10 and -100 represented maintaining shorter distance from the headway vehicle than the average driver while the values between +10 and +100 represented maintaining longer distance from the headway vehicle, (d) in regards to reaction time, values between -10 and -100 represented having slower reaction times in unexpected incidents than the average driver while the values between +10 and +100 represented having faster reaction times in comparison to the average driver and (e) in regards to steering wheel position variation, the values between -10 and -100 represented having a more unstable hold of the wheel in comparison to an average driver while the values between +10 and +100 represented having a more stable hold of the wheel as compared to the average driver. For each driving variable, the scale was completed separately for the two driving environments, namely the rural and urban driving condition.

This methodology was thought to provide the opportunity for a detailed estimation of performance, incorporating a number of qualitative characteristics as regards their driving but in a way easily comprehensible by the participants. Additionally, specific variables offered by the simulator (namely reaction time and steer wheel variation) could also be also utilized as indicators of safe or unsafe driving performance and could also designate signs of overestimated ability by the participants.

In order to assess the capacity of the participants to estimate their performance, we extracted the raw scores of the aforementioned driving variables by the simulator and converted them into z-scores, based on the performance of the control group. Then, z-scores were converted into percentiles using a linear transformation method described in Strauss et al. (2006). Similarly, the percentages extracted from the self-assessment scale were converted to percentiles according to the following formula:

$50^{th} + 50^{th} * $ (percentage better or worse than average/100)

For example, if a participant rated his reaction time as 30% better than other people of his own age and educational level, he would be ranked at the 65^{th} percentile according to the following calculations: $50^{th} + 50^{th} * $ (percentage better or worse than average/100) = $50^{th} + 50^{th} * (30/100) = 50^{th} + 15^{th} = 65^{th}$.

It should be noted that higher or lower scores in the various subjective and objective driving measures were not necessarily representative of a better/worse driving performance but signified the amount of difference (subjective or objective) that existed from the average driving behavior. The only exception would be the variables of reaction time and steer wheel angle variation, in which both raw scores and their corresponding percentiles could be considered as indicators of intact or impaired driving ability.

Results

Demographic variables

Both groups were similar in terms of age, educational level and years of driving experience. Table 1 presents the demographic characteristics as well as the driving performance of the two groups.

Table 1. Demographic variables and driving performance of the MCI and control group on various driving indexes

Measures	*Controls* *Mean(SD)*	*MCI* *Mean(SD)*	*t-test*	*Group Differences (p-value)*
Demographic Variables				
Age (years)	63.01 (±7.8)	66.59 (±8.2)	-1.623	p=0.111
Education (years)	15.11 (±3.36)	13.44 (±3.6)	1.734	p=0.089
Driving Experience (years)	35.73 (±6.7)	37.96 (±7.1)	-1.178	p=0.244

Driving Variables				
Rural				
Average Speed (km/h)	43.01 (±5.9)	36.97 (±6.4)	3.486	*p*=0.001*
Lateral Position (m)	1.58 (±0.13)	1.63 (±0.11)	-1.243	*p*=0.220
Average Headway (m)	203.91 (±132.8)	303.51 (±117.73)	-2.836	*p*=0.007*
Reaction Time (msec)	1611.96 (±315.14)	2202.86 (±656.33)	-4.072	*p*<0.001**
Steer Wheel Variation (degrees)	17.01 (±1.2)	16.13 (±1.2)	2.633	*p*=0.011*
Urban				
Average Speed (km/h)	28.18 (±4.58)	26.07 (±3.84)	1.718	p=0.093
Lateral Position (m)	3.21 (±0.67)	3.61 (±0.49)	-2.319	p=0.025*
Average Headway (m)	70.84 (±29.27)	70.32 (±23.21)	0.069	p=0.945
Reaction Time (msec)	1293.1 (±373.61)	1457.1 (±244.56)	-1.750	p=0.078
Steer Wheel Variation (degrees)	21.05 (±5.92)	24.84 (±11.96)	-1.347	p=0.185

Note. Average Speed was measured as the actual speed of the vehicle in kilometers per hour, Headway Distance was measured as the distance to ahead driving vehicle in meters, Lateral Position was measured as the average distance to the right road board in meters, Reaction Time was measured as the time between the obstacle's first move towards the road and the breaking time in milliseconds and Steer Wheel Variation was measured as the standard deviation of the steering wheel position in degrees.
$*p<0.05$, $**p<0.001$

According to the results, in the rural environment, the two groups were significantly different in all driving indexes examined with the exception of lateral position (*p*=0.220). More specifically, participants belonging to the MCI group drove at a slower speed (*p*=0.001), maintained longer distances from the headway vehicle (*p*=0.007), had significantly slower reaction times (*p*<0.001) and presented lower variability in steer wheel angle than the control group (*p*=0.011).

On the other hand, in the urban environment, the two groups presented similar performances across most of the driving variables examined. However, regarding the driving behavior of the MCI group, specific trends that resembled the driving performance of the specific group in the rural environment were also observed, especially at maintaining slower speed and having slower reaction times. The only exception where statistical significance was observed was lateral position, in which individuals from the MCI group were driving more on the right side of the road in comparison to the control group (*p*=0.025).

Subsequently, Table 2 presents subjective and objective driving performance expressed in percentiles (mean values and standard deviations) in cognitively healthy participants and patients with MCI. The specific table is provided below to serve as the reference that formed the basis for the main body of the mixed ANOVA analysis that followed through.

Table 2. Objective and subjective driving performance in the rural and urban environment for each group separately expressed as percentiles

	Objective performance		Subjective performance	
	Controls (Mean ±SD)	MCI (Mean ±SD)	Controls (Mean ±SD)	MCI (Mean ±SD)
Rural				
Speed	57.52 ± 28.44	24.31 ± 26.64	44.03 ± 18.33	42.22 ± 20.25
Headway	48.44 ± 30.84	71.03 ± 24.54	59.61 ± 14.14	60.37 ± 16.69
Lateral position	52.52 ± 30.08	62.69 ± 26.52	55.38 ± 13.11	56.48 ± 22.39
Reaction time	50.76 ± 31.86	20.88 ± 24.31	54.61 ± 13.77	51.85 ± 14.62
Std Wheel	51.32 ± 30.26	70.07 ± 27.54	57.88 ± 17.84	55.37 ± 16.57
Urban				
Speed	49.81 ± 31.13	37.0 ± 24.51	43.65 ±15.13	39.61 ± 18.59
Headway	48.81 ± 30.66	49.6 ± 25.83	58.46 ± 14.26	62.5 ± 14.78
Lateral position	51.09 ± 30.6	70.28 ± 23.21	53.07± 12.41	56.53 ± 20.33
Reaction time	52.85 ± 28.56	37.21 ± 19.51	53.84 ± 13.73	51.15 ± 15.38
Std Wheel	49.77 ± 22.46	45.12 ± 21.82	60 ± 17.01	54.23 ± 16.71

Note. Speed=Average speed, Headway=Headway distance, Lateral=Lateral position, Std Wheel=Steering wheel angle variation
$*p<0.05$, $**p<0.001$

A mixed between-within subjects analysis of variance (mixed ANOVA) was conducted to explore differences between the subjective and objective evaluation of driving performance as well as whether the clinical diagnosis (MCI vs. control group) moderates the amount of difference between the subjective and the objective evaluation of driving performance.

Table 3 presents the impact of clinical diagnosis on the level of discrepancy between objective and subjective performance on the various driving variables examined.

Table 3. Mixed between-within subjects analysis of variance and exploration of the impact of clinical diagnosis on the level of discrepancy between objective and subjective performance.

	Rural				Urban			
	Df	*F*	η^2	*p*	*Df*	*F*	η^2	*p*
Speed								
Speed	1	.186	.004	.669	1	.276	.006	.602
Speed*Diagnosis	1	14.995	.234	.000**	1	1.386	.030	.245
Error	51				51			
Headway								
Headway	1	.026	.001	.872	1	7.915	.150	.007*
Headway*Diagnosis	1	7.526	.133	.008*	1	.036	.001	.850
Error	51				51			
Lateral								
Lateral	1	.049	.001	.825	1	1.528	.033	.223
Lateral*Diagnosis	1	1.406	.028	.241	1	3.778	.077	.058
Error	51				51			
Reaction time								
Reaction time	1	14.103	.223	.000**	1	4.778	.102	.034*
Reaction time*Diagnosis	1	8.271	.144	.006*	1	1.527	.035	.223
Error	51				51			
Steer Wheel Variation								
StdWheel	1	.884	.018	.352	1	6.397	.124	.015*
StdWheel*Diagnosis	1	5.649	.103	.021*	1	.138	.003	.712
Error	51				51			

Note. Speed=Average speed, Headway=Headway distance, Lateral=Lateral position, Std Wheel=Steering wheel angle variation
**p<0.05*, ***p<0.001*

According to our results, in the rural environment, there was a significant interaction effect between clinical diagnosis and performance on the following measures: (a) average speed, [$F(1,51)=14.95$, $p<0.001$, partial $\eta^2=.234$] where the MCI group reported maintaining faster speed at the driving experiment than their actual speed whereas this pattern was not observed in the cognitively healthy drivers [Figure 1(a)], (b) headway distance [$F(1,51)=7.52$, $p=0.008$, partial $\eta^2=.133$] where the MCI group estimated having smaller distances from the headway vehicle than they actually had, whereas the cognitively healthy drivers showed the opposite trend [Figure 1(b)], (c) reaction time [$F(1,51)=8.27$, $p=0.006$, partial $\eta^2=.144$] where the clinical group overestimated the speed of their reaction times to unexpected incidents whereas the cognitively healthy drivers showed the capacity to make accurate estimations of their reaction time [Figure 1(c)] and (d) steer wheel variation [F(1,51)=5.65, p=0.021, partial η^2=.103] where the MCI group underestimated their performance and reported having greater variability in their steer wheel position than they actually did whereas this pattern was not observed in the cognitively healthy drivers [Figure 1(d)]. Additionally, a main effect of reaction time was also observed [F(1,51)=14.103, $p\leq$0.001, partial η^2=.223] reflecting the tendency of the participants to overestimate their reaction time [Figure 1(c)].

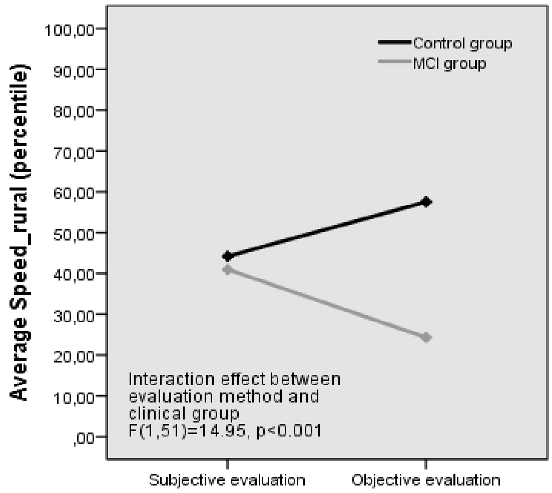

Figure 1(a). Interaction of clinical diagnosis on the subjective and objective evaluation of average speed

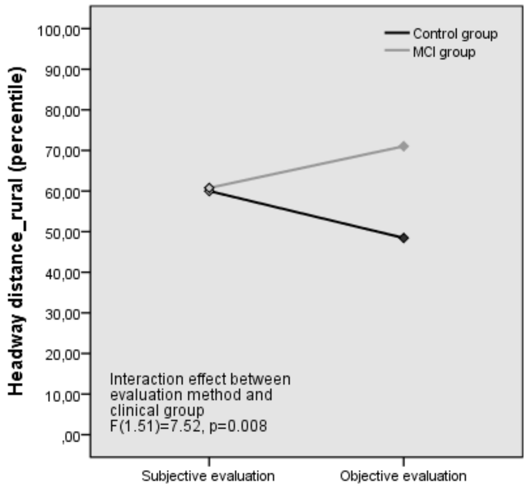

Figure 1(b). Interaction of clinical diagnosis on the subjective and objective evaluation of headway distance

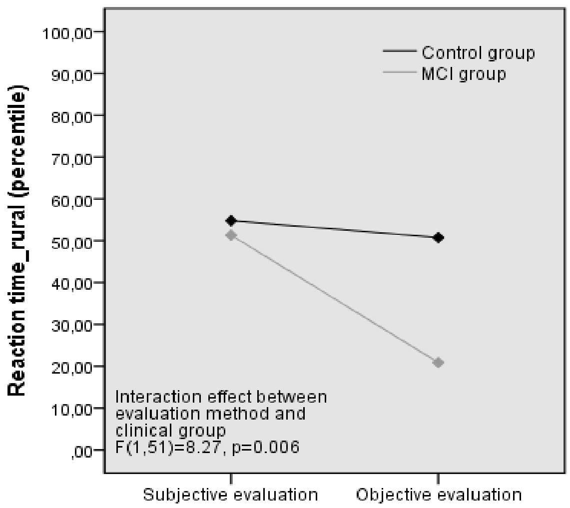

Figure 1(c). Interaction of clinical diagnosis on the subjective and objective evaluation of reaction time

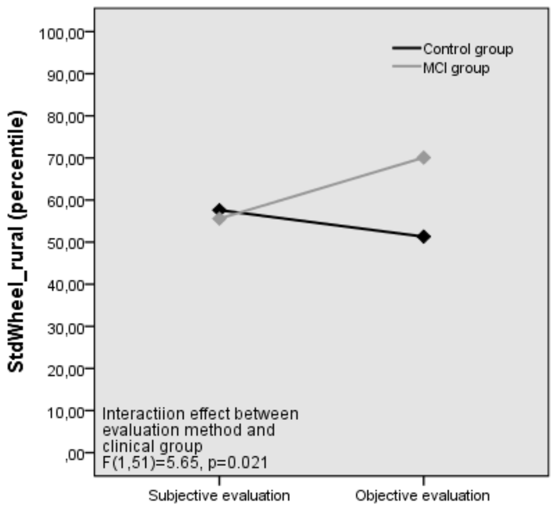

Figure 1(d). Interaction of clinical diagnosis on the subjective and objective evaluation of steer wheel angle variation

Figure 1. Interaction of clinical diagnosis with subjective and objective estimation of driving performance on various driving indexes in the rural environment. Numbers “1” and “2” on the x-axis

represent the two distinct driving evaluation conditions, namely subjective and objective driving performance respectively. The y-axis represents driving performance expressed in percentiles. The light blue line represents the control group, while the light green line represents the MCI group. R2_Speed=Average speed; R2_HWay= Headway distance; R2_Reaction= Reaction time; R2_StdWheel= Steering wheel angle variation.

In the urban environment, no significant interaction effects were observed. However, some main effects were observed for the following measures: (a) Headway distance, [$F(1,51)=7.915$, $p=0.007$, partial $\eta^2=.150$] indicating a tendency for the participants of both groups to estimate longer headway distances that they actually did, (b) Reaction time [$F(1,51)=4.778$, $p=0.034$, partial $\eta^2=.102$] reflecting the tendency of the participants to slightly overestimate their reaction time and (c) Steer Wheel Variation [$F(1,51)=6.397$, $p=0.015$, partial $\eta^2=.124$] reflecting a tendency of the participants to report better reaction times than they actually did.

Discussion

The objective of this study was to investigate whether drivers with MCI present distorted self-awareness in regards to their driving abilities in comparison to a group of cognitively healthy elderly drivers. For the purpose of this study, we utilized a driving simulator as an objective measurement of driving fitness and compared their performance on the simulator to the subjective self-reports derived from the participants themselves. The driving simulator is an assessment tool that has been verified to be ecologically valid and represent adequately everyday driving situations which otherwise could not be evaluated through a standardized on-road driving assessment, like the appearance of an unexpected incident on the road (Lee et al., 2001).

Current research so far has focused mainly on healthy elderly drivers without cognitive impairments. Thus, studies investigating self-awareness of driving ability in individuals considered to meet the criteria of MCI are sparse. Another limitation of the current literature is the exploration of driving fitness solely through the utilization of questionnaires. In other words, the existing studies exploring driving self-awareness patterns in the healthy population adopt a rather general approach to the investigation of self-regulatory driving patterns and driving avoidance behaviors by using as a reference point their premorbid driving capacity. The studies that have utilized more objective methodology regarding self-awareness have mostly focused on cognitive abilities and more specifically memory performance. Those studies commonly suggest that some degree of impaired self-awareness does exist in the particular population. Up to our knowledge, no previous studies have focused on evaluating self-perceived driving ability by using as a base for the comparisons objective measures of driving behavior. Even more, there is absence of previous research examining self-awareness on specific aspects of driving, such as how they estimate the position of their vehicle in the lane and how responsive they can be to unexpected events. Taking into account those findings, and the gap in the literature, we sought to integrate into our study a more objective methodology for the evaluation of self-awareness in driving fitness of the MCI group as well, in order to approach the methodology presented at studies evaluating self-awareness of cognitive abilities.

In line with our hypothesis, our results indicate that patients with MCI present significant difficulties to estimate accurately their performance on the simulator in comparison to their healthy counterparts. Moreover, the nature of the environment under which they are required to monitor their performance seems to contribute significantly on the level of accurate self-awareness they present regarding their driving.

In the rural environment, the MCI group failed to evaluate correctly their performance in measures of average speed, headway distance, reaction time and steer wheel angle variation. The specific finding was even more prominent in the case of reaction time, where the MCI group overestimated significantly their ability to respond to unexpected events and react to incoming stimuli.

According to several researchers, older drivers frequently recruit a variety of compensatory strategies to counterbalance the attenuation of their mental and physical skills. For example, they may avoid driving at rush hours or night, or they may drive at lower speed and maintain longer headway distances (Holland, 2002).

Our results indicate that MCI drivers adopt more prominent compensatory behaviors by driving at even lower speeds and longer distances from the headway vehicle in comparison to healthy elderly drivers. However, their self-reports on the specific variables were the opposite, suggesting a driving behavior that resembled the average performance of a person of their own age and educational level [Figures 1(a) and 1(b) of the Results section].

Patients with MCI often experience a decline in their mental and functional capacities which may often serve as a primary indicator of underlying brain pathology. According to the Petersen criteria (2004), the presence of subjective memory complaints is one of the main clinical features for the diagnosis of MCI. However, as discussed in a previous work (Fragkiadaki et al., 2016), patients with MCI show impaired self-awareness of their cognitive abilities despite the presence of subjective memory complaints. According to our results, MCI patients seemed to maintain better ability to take advantage of external cues, monitor their performance and identify probable difficulties on everyday activities in contrast with the process of a novel experience such as the neuropsychological testing procedure where they consistently overestimated their performance in comparison to age-matched healthy participants.

Similarly, it seems that drivers with MCI would acknowledge the existence of enhanced difficulties on their driving performance on the simulator and alternate their driving behavior accordingly without, however, explicitly disclosing the implementation of compensatory strategies. Thus, they reported their performance on the simulator as equal with that of their healthy counterparts. On the other hand, cognitively healthy participants were more conservative on their estimations and presented better overall accuracy of their driving performance. The pattern of self-reports observed from the MCI group could be attributed to a failure of the latter to acknowledge that their current driving behavior does not represent the norm for people of their own age and educational level but rather signifies an abnormal driving pattern.

Our results indicate that patients with MCI are incapable of estimating accurately essential characteristics of a driving session. More importantly, in the case of reaction time, which is a measure that can represent a potentially unsafe driving behavior and cannot be easily regulated, patients with MCI significantly overestimated their ability to respond to unexpected events in contrast to the control group who evaluated accurately their performance. The additional fact that their performance was significantly worse from their healthy counterparts raises questions as regards the driving behavior those patients may adopt in real life.

Several authors support the notion that driving is a complex and demanding task and great concern has been raised regarding the potential driving safety of older drivers with cognitive impairments. While many studies agree that driving ability in patients with dementia is heavily compromised (Man-Son Hing et al., 2007; Uc et al., 2006; Lincoln et al., 2009), driving ability of individuals with MCI seems to be better preserved. The latest line of research suggests that most patients with MCI are not necessarily incapable drivers, although various deficits in driving measures in comparison to healthy elderly drivers have also been reported (Wadley et al., 2009; Devlin et al., 2012; Frittelli et al., 2009).

Research regarding driving self-awareness in patients with MCI is limited, and conclusions have not been safely drawn. While other researchers state that patients with MCI report functional decline, including driving (Farias et al., 2005), others raise concerns as regards the effect of cognitive impairment on the ability of an individual to accurately estimate and regulate driving performance (Okonkwo et al., 2009; Devlin et al., 2014). For example, a review conducted by Devlin et al. (2014) demonstrated that the majority of elderly drivers with cognitive impairments do restrict their driving behavior and regulate their driving habits in accordance with their modified capabilities. However, in the specific review, the authors did not conclude into whether these restrictions derive from their own subjective judgment regarding cognitive and functional decline or whether impaired insight does exist in the specific population and those restrictions are being encouraged by external factors.

Nevertheless, up to our knowledge, no studies have compared self-awareness of driving ability with specific objective measures of driving performance. This is the first study to explore in detail driving performance in patients with MCI through a driving simulator and attempt direct comparisons with the self-reports derived from the participants regarding specific aspects of driving performance.

What is more, it should be taken into account that patients with amnestic MCI often share common neuropathological ground with Alzheimer's Disease (AD) (Albert et al., 2011). According to research investigating the self-awareness profile of patients with AD, the level of insight is usually linearly correlated to the level of cognitive impairment (Kazui et al., 2006; Aalten et al., 2005; Barrett et al., 2005). Several studies also address that AD patients, present impaired insight into their driving difficulties (Wild & Cotrell, 2003; Uc et al., 2005; Uc et al., 2006; Ott et al., 2008). For example, a study reported that, from a sample of AD patients in which all of them considered themselves as safe drivers, 38% failed the on-road test (Hunt et al., 1993). Thus, in the absence of concrete state guidelines, driving regulation and overall cessation is to be determined by the patient and their caregivers, both of whom may fail to evaluate objectively driving performance (Okonkwo et al., 2009; Clare et al., 2005)

In our study, the discrepancies observed between objective and subjective performance in the MCI group were significantly different depending on the condition examined. More specifically, in contrast to the rural environment where significant differences were observed between the two groups on most of the variables examined, in the urban environment, the two groups presented similar levels of discrepancy between objective and subjective performance at three driving variables (headway distance, reaction time and steer wheel angle variation).

This finding could be attributed to the different levels of cues provided by the two environments. The rural environment was representative of a typical Greek countryside without any distinct surroundings. On the other hand, the urban environment offered a more structured and organized surrounding with multiple signs and cues from both sides of the road. Additionally, all participants of the study were residents of a large city; therefore the urban environment was considered to be more familiar with them.

Along this vein, a review study examining the best metacognitive strategies that could potentially enhance self-assessment abilities in everyday practice (Eva & Regehr, 2005), concluded that individuals regularly take advantage of external cues in order to improve their subjective evaluation regarding a specific performance and to outline specific attributes to themselves concerning their strengths and weaknesses. Under this perspective, and taking into account the specific structure of the urban environment by the driving simulator, the improved performance of the MCI participants at the second driving condition could be accredited to the greater number of cues available, namely the presence of more frequent road signs, straighter road lanes, parked vehicles on both sides of the road and a greater number of intersections.

The utility of providing feedback as regards driving performance has also been reported by previous research (Owsley et al., 2003; Tuokko et al., 2007; McKenna & Myers, 1997). Those studies claim that when appropriate feedback regarding specific aspects of driving ability is available, older drivers may be more prone to adjusting their driving behavior in comparison to relying solely on their own subjective estimations of their driving ability. For example, in a study by Eby et al. (2003), when older drivers were required to reflect on their physical and mental skills, including driving, and complete a workbook by taking under account cues that could signify change in those areas, 14% of them reported having a greater overview of probable changes in their driving skills and 25% of them reported an intention to modify their future driving behavior. As most of those studies suggest, when feedback regarding driving ability is available, better decisions can be drawn regarding future modification of driving behavior (Owsley et al., 2003) leading to fewer overall driving errors and adverse driving incidents (Ackerman et al., 2011). In the case of cognitive impairment, however, especially at the more severe stages, lack of awareness regarding cognitive and functional deficits could potentially interfere with adjustments to driving behavior (Kalbe et al., 2005; Clément et al., 2008). For that reason, providing cues for reflection of driving ability could deliver similar results regarding driving behavior modification observed in cognitively intact elderly drivers. Such a concept, although it has not been implemented in drivers with cognitive impairments, could serve as a useful strategy for the enhancement of metacognitive abilities in patients with MCI and the overall improvement of their driving performance.