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Elderly drivers with brain disorders: Is their driving behavior the same before and after an unexpected incident?

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Abstract

The objective of this study is the comparison of driving behaviour of elderly drivers before and after an unexpected incident, by applying a large driving simulator experiment. More specifically, the impact of the presence of a brain disorder (Alzheimer's, Parkinson's disease, and Mild Cognitive Impairment), and the mobile phone use while driving is investigated. The driving behaviour was examined in terms of lateral position and mean driving speed. The driving task included driving in rural road, while various unexpected incidents were scheduled to occur. 125 elderly participants went through the whole experimental procedure. The General Linear Mixed Models indicated that all three diseases and the use of mobile phone were found to significantly affect the model regarding the driving speed before and after the incident. Analysing the lateral control measure it was observed that only PD out of the three examined diseases had a significant impact on the model.

Keywords: driving behaviour; unexpected incident; brain disorders; driving simulator

1. Introduction

Driving in traffic is not just knowing how to handle the basic operating mechanisms of the vehicle, but it is a task of high cognitive complexity which requires the driver to be able to receive sensory information, process this information quickly, and make proper, timely judgments and responses. Cognitive functions which decline over age are of critical importance regarding driving performance. Diseases affecting a person's brain functioning, may significantly impair the person's driving performance, especially when unexpected incidents occur. A number of prevalent neurological diseases may be involved, ranging from very mild to severe states that include Parkinson's or Alzheimer's disease, Cerebrovascular disease etc. (Wood et al., 2005; Cordell et al., 2008; Cubo et al., 2009; Frittelli et al., 2009).

The objective of the present paper is the comparison of driving behaviour of elderly drivers before and after an unexpected incident, by applying a large driving simulator experiment. More specifically, the impact of several risk factors namely, the presence of a neurological disease affecting cognition, and the mobile phone use while driving is investigated. The driving behaviour was examined in terms of lateral position and mean driving speed of the vehicle and the neurological diseases affecting cognitive functions concern diseases with high prevalence in the general population: Alzheimer's disease (AD), Parkinson's disease (PD), and Mild Cognitive Impairment (MCI).

2. Data collection

2.1 Driving simulator experiment

An interdisciplinary research team of engineers, neurologists and psychologists (Yannis et al., 2013) cooperated in order to design and conduct the experimental procedure. The experiment includes three types of assessment: a) Neurological assessment which concerns the administration of a full clinical medical, ophthalmological and neurological evaluation, in order to well document the characteristics of each of these cerebral diseases, b) Neuropsychological assessment which concerns the administration of a series of neuropsychological tests and psychological-behavioral questionnaires to the participants, covering a large spectrum of Cognitive Functions: visuospatial and verbal episodic and working memory, general selective and divided attention, reaction time, processing speed, psychomotor speed etc., and c) Driving at the simulator assessment which concerns the programming of a set of driving tasks into the driving simulator for different driving scenarios.

The driving simulator that was used is placed at the National Technical University of Athens. The NTUA driving simulator is a motion base quarter-cab manufactured by the FOERST Company. The simulator consists of 3 LCD wide screens 40'' (full HD: 1920x1080pixels), driving position and support motion base. The dimensions at a full development are 230x180cm, while the base width is 78cm and the total field of view is 170 degrees.

The driving simulator experimental procedure started with a 10-15-minute familiarization drive on the basis of several quantitative and qualitative criteria, until the participant fully familiarized with the simulation environment. Afterwards, all participants drove at a rural route that was 2.1 km long, single carriageway, lane width was 3m, with zero gradient and mild horizontal curves. The three distraction conditions concerned: a) undistracted driving, b) driving while conversing with a passenger and c) driving while conversing through a hand-held mobile phone. Moreover, during each trial, two unexpected incidents were scheduled to occur: sudden appearance of an animal (deer or donkey) on the roadway in the rural session (Figure 1).

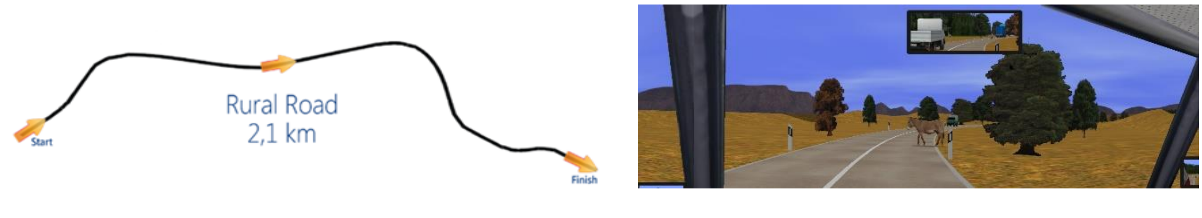

Figure 1. Top view of the road environment and a respective screenshot from the driver's perspective

2.2 Sample characteristics

The sampling scheme included 125 participants (76% males - 24% females) of more than 55 years of age and of similar demographics went through the whole experimental procedure: 34 healthy controls, 43 MCI, 28 AD, and 20 PD patients. The clustering process regarding the neurological state of the participants is beyond the scope of this paper and was made after a large battery of neurological and neuropsychological tests (Yannis et al., 2013). It is important to mention though, that together with the confirmation of cognitive impairments, all MCI patients had Clinical Dementia Rating (CDR) = 0.5 and all AD patients had CDR=1.0 (Morris, 1993) (all controls had no cognitive impairments and a CDR score equal to zero).

3. Methodology

The driving at the simulator experiment data storage was performed automatically at the end of each experiment. The data was stored in text format (*.txt). The simulator records data at intervals of 33 to 50 milliseconds which means that each second measured values for each variable up to 30 times. At first, 33 variables were recorded in each session. The driving performance measures that are collected after each experiment include, mean speed, headway, lateral position, steering angle, reaction time, accident probability and several other parameters. The large database that was extracted from the experimental process was analyzed with data reduction techniques which include 5 data processing levels.

In order to fulfil the purpose of this study, new variables were created which are calculated as the difference of the mean value of each driving parameter after and before the incident. More specifically, the data that concerned 20 seconds before the start of the event and 20 seconds after the event is completed, were isolated and the mean value for the two periods of driving was calculated. The statistical methodology that was selected was regression analysis through 2 General Linear Mixed Models in order to mathematically quantify the impact of the examined cerebral diseases (Alzheimer's Disease - AD, Parkinson's Disease - PD, and Mild Cognitive Impairment – MCI) and of other risk factors to the driving performance and specifically to mean speed and the lateral position of the vehicle.

4. Results

4.1 Mean speed before and after an unexpected incident

The first linear regression model explores the relationship between the average speed before and the average speed after an unexpected incident and other parameters such as the use of a mobile phone, the characteristics of the driver and, of course, the presence of the three examined brain disorders. The table below (Table 1) shows the results of the General Linear Mixed Model.

Table 1. GLM parameter estimates for **mean speed before and after an unexpected incident**

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	-28.38610	0.49819	-56.979	< 2e-16 ***
Mobile Phone	-1.71903	0.47038	-3.655	0.000265 ***
PD	-4.55300	0.67259	-6.769	1.76e-11 ***
AD	-3.47828	0.66449	-5.234	1.85e-07 ***
MCI	-1.98399	0.53569	-3.704	0.000219 ***
Gender	-1.02829	0.40849	-2.517	0.011914 *
Experience	0.10401	0.01395	7.454	1.41e-13 ***
*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*				

It is observed that the existence of MCI, AD, PD, as well as gender and driving experience statistically significantly affect driving speed before and after an unexpected event. More specifically, the existence of PD has the greatest influence on the model and it seems that after an unexpected event leads to a significant reduction of speed. Also the use of a mobile phone seems to lead to a reduction in driving speed after an event, possibly in order to compensate the complexity of this driving condition.

4.2 Lateral position before and after an unexpected incident

The second General Linear Mixed model explores the relationship between the lateral position before and the lateral position after an unexpected event and other parameters such as the use of a mobile phone, the characteristics of the driver and, of course, the presence of the three examined brain diseases. The table below (Table 2) shows the results of the GLM.

Table 2. GLM parameter estimates for **mean speed before and after an unexpected incident**

Coefficients:	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
Intercept	-0.0216887	0.0201678	-1.075	0.282337
Mobile phone	-0.0672646	0.0196152	-3.429	0.000619 ***
PD	-0.0488388	0.0261293	-2.169	0.041772 *
Gender	-0.0616699	0.0167618	-3.679	0.000241 ***
Experience	0.0016211	0.0004911	3.301	0.000984 ***
*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*				

It is noted that the existence of PD, as well as gender and driving experience significantly affect the lateral position before and after an unexpected event. In particular, all these factors lead the driver to drive more closely to the right border of the road after an event, following a more conservative driving.

5. Conclusions

The objective of this study was to compare the driving behaviour of elderly drivers, with or without some neurological disorder affecting their proper cognitive functionality such as the Alzheimer's Disease, the Parkinson's Disease and the Mild Cognitive Impairment, before and after an unexpected incident, by applying a large driving simulator experiment. The regression analysis focused on investigating the impact of the brain disorders and of the mobile phone use on the mean speed of the drivers and the lateral position of their vehicles, before and after an unexpected incident. The results of these analyses lead us to the conclusion that an unexpected incident surprises the drivers with neurological conditions that affect cognitive functions and then forces them to maintain a more cautious and conservative pattern of driving behavior, compared to the control group, which seem unaffected by the incident regarding their driving performance. This study suggests that drivers with brain disorder have difficulties in their driving performance in comparison with the healthy controls and they are aware of that, especially when something unexpected is happening. Further research is required in order to validate the relationships between medical, neuropsychological and driving impairments for different brain disorders and in different contexts, allowing to improve and test appropriate recommendations and potential monitoring and licensing schemes for older and cognitively impaired drivers, especially as regards the early and subtle changes observed in MCI and AD. Finally, it would be of great interest, to design a scenario where the participants are placed in a wider range of conditions that provide greater scope to display in more detail, possible compensatory mechanisms.

6. References

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