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Can we predict safe driving for the elderly through a self-assessment of driving behaviour?

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Περίληψη

Στόχος αυτής της εργασίας είναι η απόκτηση πρακτικής γνώσης και μεθοδολογίας που θα βελτιώσει τις υπάρχουσες συστάσεις περί καταλληλότητας ή μη οδήγησης, υποδεικνύοντας τους οδηγούς ηλικίας άνω των 60 ετών που ενδέχεται να έχουν επικίνδυνη συμπεριφορά στην οδήγηση μέσω ενός ερωτηματολογίου αυτοαξιολόγησης οδηγικής συμπεριφοράς. Η μεθοδολογική προσέγγιση περιλαμβάνει συσχέτιση ενός ερωτηματολογίου συμπεριφοράς οδηγού με δείκτες οδηγικής επίδοσης ηλικιωμένων οδηγών που ολοκλήρωσαν ένα πείραμα προσομοιωτή οδήγησης. Για το σκοπό αυτό, αναπτύχθηκε ένα ερωτηματολόγιο αυτοαξιολόγησης και συμπληρώθηκε από περισσότερους από 100 συμμετέχοντες. Οι οδηγοί πέρασαν από ένα πείραμα προσομοίωσης οδήγησης το οποίο περιελάμβανε οδήγηση σε υπεραστικό και αστικό περιβάλλον οδήγησης, ενώ ορισμένα απρόσμενα συμβάντα είχαν προγραμματιστεί να συμβούν κατά τη διάρκεια της οδήγησης προκειμένου να μελετηθεί ο χρόνος αντίδρασής τους και η πιθανότητα ατυχήματος. Τα αποτελέσματα έδειξαν ότι οι ηλικιωμένοι οδηγοί που δήλωσαν ότι οι οδηγικές τους δεξιότητες έχουν επιδεινωθεί σε μεγάλο βαθμό τα τελευταία πέντε χρόνια, ήταν στην πραγματικότητα οι πιο αργοί οδηγοί, είχαν τα περισσότερα λάθη οδήγησης, τους χειρότερους χρόνους αντίδρασης και την υψηλότερη πιθανότητα ατυχήματος. Οι οδηγοί που δηλώνουν ότι αποφεύγουν να οδηγούν μόνοι τους είχαν σχεδόν 100% πιθανότητα ατυχήματος σε ένα απρόσμενο συμβάν. Συνολικά, υπάρχουν σαφή μοτίβα που ακολουθούν οι ηλικιωμένοι οδηγοί στις απαντήσεις αυτοαξιολόγησης που υποδεικνύουν μη ασφαλή οδική συμπεριφορά και αυτό επικυρώνεται από το πείραμα του προσομοιωτή.
Λέξεις κλειδιά: *Οδηγοί μεγαλύτερης ηλικίας, Αυτοαξιολόγηση, Οδηγική συμπεριφορά, Ασφαλής οδήγηση*

Abstract

The aim of this paper is to obtain practical knowledge that will improve existing driving recommendations by indicating those drivers of over than 60 years old that might have a dangerous driving performance through a self-assessment driving behaviour questionnaire. The methodological approach includes correlation of a driver behavior questionnaire with driving behaviour indicators of older drivers who completed a driving simulator experiment. For this purpose, a structured self-assessment questionnaire was developed and filled in by more than 100 older participants. Afterwards, the older drivers went through a “driving at the simulator” experiment which included driving in rural and urban driving environment with normal conditions while some unexpected incidents were scheduled to occur during the driving sessions in order to study their reaction time and their accident probability. Results indicated that the older drivers who self-declared that their driving skills have been deteriorated over the last five years in a great extent, were actually the slower drivers, they had the more driving errors, had the worse reaction times and the higher accident probability. The older drivers who avoid driving alone had almost 100% accident probability in an unexpected incident. Overall, there are clear patterns which older drivers follow in their self-assessment answers indicating unsafe driving behaviour and this is validated by the simulator experiment.

Keywords: *Older drivers, Self-assessment, Driving behaviour, Safe driving*

1. Background

Driving is a quite difficult task that requires the utilization of a wide range of individual skills as well as practical and psychological abilities. Drivers should have good spatial perception and well-coordinated control in order to manage multiple stimuli simultaneously, make timely judgments or responses and react quickly in case of an emergency when completing the driving processing (De Oliveira, at al., 2012). The normal aging process is associated with increasing motor, cognitive, visual, perceptual and sensory impairments. In particular, specific changes include motor skills such as physical strength, manual dexterity or neck flexibility (Schwebel, et al., 2007), cognition such as processing speed, selective and divided attention, fluid intelligence or executive functioning (Bakhtiari et al., 2021), vision such as contrast sensitivity, visual acuity or sensitivity to glare (Selander, et al., 2021), perception such as reaction time or motion perception (Biernacki, et al., 2021) and sensory function, such as acuity and contrast sensitivity (Anstey, et al., 2005). The aforementioned difficulties can affect various domains, some of which are closely related to driving performance. Due to advanced age, a functional decline in the memory, physical fitness and flexibility needed for safe driving can lead to a significant deterioration in driving ability and an increased risk of road accident.

Older adult drivers are more likely to experience not only complicated conditions but also challenging driving situations that can directly affect their ability to control a motor vehicle safely (Carr et al., 2010). It should be mentioned that the age-group refers to as older adult drivers is the one of 75 years and above. According to European Commission (European Commission, 2018), older drivers have the second highest fatality rate in traffic of all age-groups. At the same time, they do not consist so much a risk to others, but they are at risk themselves due to their vulnerability and frailty to the increased injury severity or risk of death in the event of a crash involvement. Population ageing is a global phenomenon with lasting and continued impacts on sustainable development. In general, the average age of road crash fatalities is on the rise. In the upcoming years, the problem's magnitude may further increase due to the expected increase in the total number of people more than 65 years of age, the mobility of elderly people as well as the rates of licensed older drivers. While today, over 20% of road crash fatalities involve drivers aged 60 years and above in Europe and it is expected that by the year 2050, the rate of elderly road crash fatalities will increase to 43% (European Commission, 2021). Similar growth is also expected to be achieved in the driving population. In particular, in 2011, the percentage of older drivers in the total population was 16% and by 2025, one in five drivers (20%) will be at least 65 years of age (McElligott, 2015).

In Greece, medical examination considers a part of the procedure for the acquisition or renewal of driving licenses. The legislation includes general guidelines for medical conditions that could affect driving that are subsequently described as well as about the time period that the driving license is valid, and the procedures for issuing a new driving license. For individuals up to 80 years old, without any medical history that could potentially influence safe driving, the examination for diving license is carried out by two medical doctors (a pathologist and an ophthalmologist). Those doctors are responsible for the Primary Medical Examination (Official Government Gazette B’ 1409/6-9-2010). According to the updated legislative directives, after the completion of 80 years of age, the renewal of the driving license should be made by the Secondary Medical Commission with a duration not more than two years from the date of renewal (OGG A’ 120/29-5-2013, 4155/2013).

A new Legislation regarding older drivers was recently adopted in Greece (OGG 4413/2016 A’ 148). According to this new Legislation, among other provisions, the minimum requirements for physical and mental fitness to drive were revised and all 80 years old drivers must complete a neurological, neuropsychological and psychiatric assessment in order to be considered as fit or not fit to drive. However, a significant gap is detected, which is constructed by the legislative ambiguity on the one

hand and the lack of the necessary tools to safely evaluate the driving behaviour and the driving competence of the elderly with or without neurological diseases on the other. This study will try to fill in this gap and suggest if there is any mechanisms which will make it easier for the scientists in order to draw safe conclusions and make decisions regarding driving cessation.

2. Methodology

2.1 General

The main goal of this study is to obtain practical knowledge that will improve existing driving recommendations in order to enhance driving safety among elderly individuals >60 years old. According to the research design, a helpful mechanism for enhancing the accuracy of recommendations for safe driving in the elderly drivers is developed. In particular, the correlation of their driving performance indicators with their self-assessment of driving behavior will create the aforementioned mechanism, through which it will be possible to predict whether an older driver is at risk or not, via several questionnaire answers that will be provided to them by their medical doctor.

2.2 The participants

For the purpose of this paper 274 participants have, at least, started the driving simulator experiment that was described analytically in the above chapters. 49 participants were eliminated from the study because they had simulator sickness issues from the very beginning of the driving simulator experiment. Thus, 225 individuals went through the whole experiment procedure. 115 participants were of younger age (<60 years old) and they were eliminated from this study too, in order not to have age as a parameter that may affects the results. Summarizing the above, 110 participants of more than 60 years of age went through the whole experimental procedure.

Table 1. Demographics of the participants

	Older drivers
Age, y, mean±SD	67.5±5.8
Gender, n, M/F	110, 65/45
Driving experience, y, mean±SD	35.9±3.7
Days/week, median (range)	5 (2-7)
Education, y, mean±SD	12.5±2.4

The following inclusion criteria were required for participation in the current study: a) valid driving license, b) more than 3 years of driving experience, c) driving more than 2500km during the last year, d) driving at least 10km/week during the last year, e) no history of psychosis, f) absence of any significant kinetic disorder that prevents them from basic driving movements, g) absence of dizziness or nausea while driving, either as a driver or as a passenger, h) absence of alcohol or any other drug addiction, i) absence of any significant eye disorder that prevents them from driving safely.

2.3 The driving at the simulator experiment

Road safety research often makes use of driving simulators, as they allow for the examination of a range of driving performance measures in a controlled, relatively realistic and safe driving environment. Driving simulators, however, vary substantially in their characteristics, and this can affect their realism and the validity of the results obtained. Despite these limitations, driving simulators are an increasingly

popular tool for measuring and analyzing driver distraction, and numerous studies have been conducted, particularly in the last decade.

The driving simulator experiment took place at the Department of Transportation Planning and Engineering of the National Technical University of Athens, where the FOERST Driving Simulator is located. 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. Research evidence from on-road testing supports the validity properties of the driving simulator that was applied in the current study (Yannis et al., 2013).

The driving simulator experiment began with one practice drive (usually 15-20 minutes), until the participant fully familiarized with the simulation environment. Afterwards, all participants continued to the two sessions. Each session corresponds to a different road environment (Figure 1): a) rural route that is 2.1km long, single carriageway and the lane width is 3m, with zero gradient and mild horizontal curves, b) an urban route that is 1.7km long, at its bigger part dual carriageway, separated by guardrails, and the lane width is 3.5m. Moreover, narrow sidewalks, commercial uses and parking are available at the roadsides. During each trial, 2 unexpected incidents were scheduled to occur at fixed points along the drive. More specifically, incidents in rural area concerned the sudden appearance of an animal (deer or donkey) on the roadway, and incidents in urban areas concerned the sudden appearance of an adult pedestrian or of a child chasing a ball on the roadway or of a car suddenly getting out of a parking position and getting in the road. Regarding the time point that the hazard appears, it depends on the speed and the time to collision in order to have identical conditions for all participants to react, either they drove fast or slowly. Thus, there was no possibility for the incident to appear closely or more suddenly to a participant than to another.

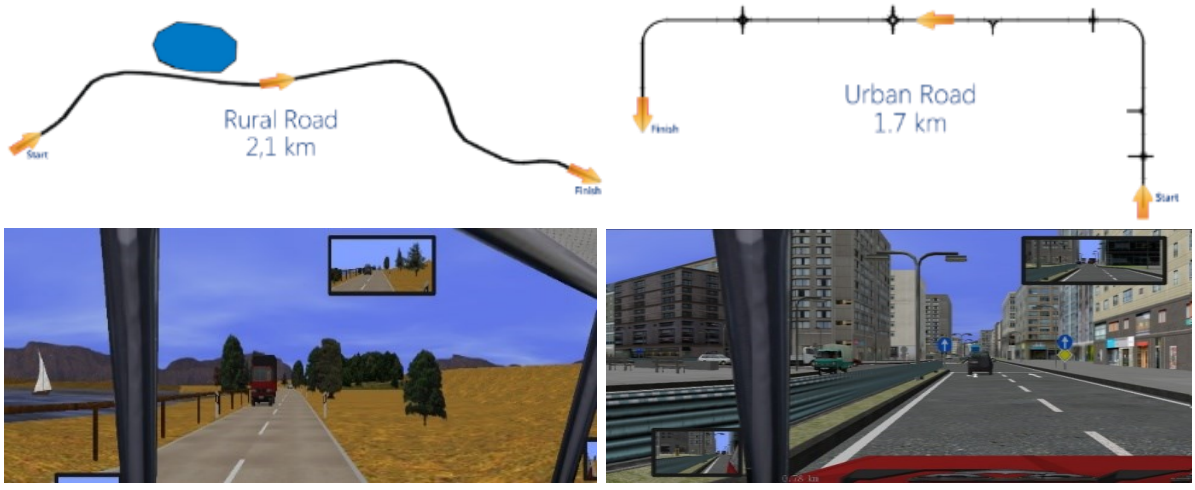

Figure. 1. The two plans of the driving routes (rural and urban) and two screenshots for each driving environment

2.4 The self-assessment questionnaire

After completing the driving session, all participants were asked to fill in a questionnaire about their driving habits and their driving behaviour. The questions are chosen carefully on the basis of the existing literature on drivers' self-reported behavior. The sections of the questionnaire are:

- Driving experience - car use

- Self -assessment of the older driver
- Distraction-related driving habits
- Emotions and behaviour of the driver
- Anger expression inventory during driving
- History of accidents, near misses, and traffic violations

The driving experience section includes questions about the driving experience and driving habits of the participants, that were used in analyses as potential moderating factors in the evaluation of driving simulator performance. The section also incorporates questions that examine the driving experience of the participants in different driving environments or situations, e.g., frequency of driving during rush hour, thus providing more detailed information on the driving experience of the participants. The section ends with a self-evaluation question on driving avoidance due to worry about one's driving.

The self-assessment of the older driver section includes two sections. The questions of the first section require the self-evaluation of the perceptual-motor and safety skills of the driver. The items of the section are derived from the Driver Skill Inventory (Lajunen & Summala, 1995), with adaptations and modifications by the research team. The section employs a 4-point scale (from weak to strong), in order to prevent the bias of responses that cluster in the middle. The section includes an original questionnaire, developed by the research team, which asks the participants to rate their driving skills in relation to their skills of 5 years ago. The rating scale ranges from no difference to significantly worse with respect to driving in different conditions (on a highway, at night, in heavy traffic, etc.). In addition, participants rate whether or not they avoid each one of the conditions included, how often, and if so, whether their avoidance is attributed to their own hesitation, the discouragement of their family, or other reasons. This section offers valuable information on self-awareness of possible driving impairment, as well as possible compensatory mechanisms to avoid safety risks. A questionnaire that inquires about the frequency of various driving difficulties is also included, on a 4 or 5-point scale (never-always). The information provided in this section will be related to the driving performance of the drivers in the different conditions of the driving simulator experiment.

3. Results

3.1 General

The objective of this paper is to obtain practical knowledge that will improve existing driving recommendations in order to enhance driving safety among elderly individuals >60 years old. For that reason, 4 key driving performance measures were examined, which correspond to both longitudinal and lateral driving control measures, in rural and urban areas, and are presented below:

- **Mean speed** - refers to the mean speed of the driver along the route, excluding the small sections in which incidents occurred, and excluding junction areas.
- **Driving errors** – refer to the number errors that the driver did (outside road line, hit of sidebars, harsh cornering, speed violations, etc.)
- **Reaction time** - refers to the time between the first appearance of the event - "obstacle" on the road and the moment the driver starts to brake.
- **Accident probability** – refer to the probability of crashing at an unexpected incident (number of actual crashes at the experiment divided to the total number of incidents)

Moreover, more than 40 questions regarding self-assessment driving issues were given to the participants. An indicative list with the most important questions is presented below.

Table 2. Indicative list of self-assessment questions

ID	Question
Q1	Do you avoid driving alone?
Q2	How many times, in the last 6 months, did you avoid driving because you were afraid of your driving skills?
Q3	How would you assess your driving performance now, in comparison with 5 years ago?
Q4	When conversing with a passenger while driving, do you usually speed down and be more careful?
Q5	How many times, in the last year, have you experienced an argument with a passenger while driving?
Q6	How often do you use your seat belt while driving?
Q7	How often do you drive without being concentrated?
Q8	How many accidents have you experienced as a driver?
Q9	How many times did you avoid an accident "at the very last moment", in the last two years?
Q10	Do you have difficulties in perceiving vehicles and pedestrians that suddenly approach in front of you?
Q11	How many times have you violated the Traffic Code as a driver, in the last two years?
Q12	How many times have you been fined because you violated the Traffic Code as a driver, in the last two years?

After many correlations between all parameters, the most highlighted results are presented below:

3.2 Mean speed

The first correlation concerns mean speed of the older driver and two questions: “How would you assess your driving performance now, in comparison with 5 years ago?” and “Do you have difficulties in perceiving vehicles and pedestrians that suddenly approach in front of you?”.

Table 3. Mean speed

	How would you assess your driving performance now, in comparison with 5 years ago?			
	Much worse	Worse	Same	Better
Older driver mean speed	35.4	37.7	39.3	45.2

	Do you have difficulties in perceiving vehicles and pedestrians that suddenly approach in front of you?			
	Never	Rarely	Sometimes	Often
Older driver mean speed	39.2	39.3	36.9	22.2

It seems that the older drivers who admit having difficulties in perceiving other vehicles and pedestrians and admit that their driving performance is significantly deteriorated over the last 5 years are driving with lower speeds compared to the ones answering in a different way. It seems that they try to compensate their low driving skills with more careful driving.

3.3 Driving errors

The second correlation concerns driving errors of the older driver and the following question: "How would you assess your driving performance now, in comparison with 5 years ago?".

Table 4. Driving Errors

	How would you assess your driving performance now, in comparison with 5 years ago?			
	Much worse	Worse	Same	Better
Older driver driving errors	3	0.7	0.6	1

It seems that the older drivers who admit that their driving performance is significantly deteriorated over the last 5 years, actually had more than 3 times more driving errors in the driving simulator experiment compared to the ones answering in a different way.

3.4 Reaction time

The third correlation concerns reaction time of the older driver at an unexpected event and the following questions: "How would you assess your driving performance now, in comparison with 5 years ago?", "Do you have difficulties in perceiving vehicles and pedestrians that suddenly approach in front of you?" and "In case of an unexpected incident your reaction time, is:"

Table 5. Reaction time

	How would you assess your driving performance now, in comparison with 5 years ago?			
	Much worse	Worse	Same	Better
Older driver reaction time	2458	2307	1934	1470
	Do you have difficulties in perceiving vehicles and pedestrians that suddenly approach in front of you?			
	Never	Rarely	Sometimes	Often
Older driver reaction time	1952	1958	2278	3250
	In case of an unexpected incident your reaction time, is:			
	Quick	Just ok	Slow	Very Slow
Older driver reaction time	1946	2048	2137	2817

It seems that the older drivers who admit having difficulties in perceiving other vehicles and pedestrians, admit that their driving performance is significantly deteriorated over the last 5 years and self-assess that their reaction time in case of an emergency is very slow, actually had the worse reaction times at the simulator experiment compared to the ones answering in a different way. Those answered "much worse" in the first question, had a reaction time of 2.5 seconds (the highest among all categories), the ones who answered "often" in the second question had 3.3 seconds reaction time (also the highest among all categories) and the ones who answered "very slow" in the last one had 2.8 seconds reaction time. It is worth highlighting that the older drivers who self-assess positively regarding the above questions had

the best reaction times. It seems that there is a strong evidence that an older driver has slow reaction times if they answer that way in the aforementioned questions.

3.5 Accident probability

The last correlation concerns accident probability of the older driver at an unexpected event and the following questions: "Do you have difficulties in perceiving vehicles and pedestrians that suddenly approach in front of you?" and "Do you avoid driving alone?"

Table 6. Accident probability

	Do you have difficulties in perceiving vehicles and pedestrians that suddenly approach in front of you?			
	Never	Rarely	Sometimes	Often
Older driver accident probability	25.0%	32.1%	31%	100%

	Do you avoid driving alone?			
	Never	Sometimes	Often	Always
Older driver accident probability	24.10%	36.40%	50%	100%

It seems that the older drivers who admit having difficulties in perceiving other vehicles and pedestrians, and self-declare that they always avoid driving alone, actually crashed all incidents at the simulator experiment. It seems that there is a very strong evidence that an older driver has high accident probability (because of their unsafe driving performance) if they answer that way in the aforementioned questions.

4. Discussion and conclusions

The main goal of this study was to obtain practical knowledge that will improve existing driving recommendations in order to enhance driving safety among elderly individuals >60 years old. A helpful mechanism for enhancing the accuracy of recommendations for safe driving in the elderly drivers was developed. In particular, the correlation of their driving performance indicators with their self-assessment of driving behavior created the aforementioned mechanism, through which it will be possible to predict whether an older driver is at risk or not, via several questionnaire answers that will be provided to them by their medical doctor.

To achieve this objective, the driving-behavior profile of the participants were assessed by using data that were obtained by conditions of simulated driving through the integration of state-of-the-art technology. This framework is expected to provide important help for filling the existing gap of the current evaluation process of elderly drivers by enhancing the accuracy of the recommendations regarding the driving ability for the elderly and by this way to enhance their quality of life.

Overall, it can be derived that there are clear patterns which older drivers follow in their self-assessment answers which indicate unsafe driving behaviour. More specifically, the older drivers who self-assessed difficulties in several categories, which means that the are aware of their deteriorated driving performance, actually had the riskiest driving profiles, namely, worse reaction times, more driving errors and higher accident probability.

What can be concluded by this study is that based on the answers that an older driver will give in these specific questions, we can classify them as probably unsafe drivers. More specifically if an older driver admits that in comparison with 5 years ago, their driving performance is deteriorated, if they admit that they avoid driving alone, if they admit having difficulties in perceiving other vehicles and pedestrians, there is a high probability that this specific older driver is no longer a safe driver. That way, this study helps enhancing the accuracy of recommendations for safe driving in the elderly drivers and the prediction of safe vs unsafe driving behavior in the specific population, which is quite important as an assessment protocol is missing and the job of the doctors and practicians when it comes to fitness (or not) – to – drive for the older drivers is very difficult.

The socioeconomic impact concerns the improvement of road safety that may be achieved for the driving population of Greece, with the development of ecologically valid guidelines that can be applied during the license renewal process of older drivers. Enhancing the accuracy of the recommendations that are provided to this vulnerable group of drivers regarding the removal or not of their driving privileges may reduce at a considerable extent the number of road crashes and fatalities, especially when taking under consideration the EU data that highlight the increased rates of accidents in individuals above 65 years old. In this direction, apart from protecting the safety of the drivers, a positive outcome may be achieved as well in the case of the economic impact that road crashes impose both on a personal and a national level.

Additionally, by taking under account the tremendous social and psychological impact that driving cessation may impose on drivers who are not considered safe to drive under the current vague legislation system in Greece, the current study will encourage the development of a personalized approach which will be based on the unique profile of each patient, their current cognitive state, the severity of the disease and the presence of behavioural symptomatology that may compromise their driving ability. This individualized perspective may enhance the level of engagement from the side of the patients and their families regarding the overall planning and the final choice of ceasing driving when this is deemed necessary.

Consequently, the results of this study will be of particular interest to older drivers, with or without cognitive disorders as well as their family environment and caregivers (through public campaigns, dissemination of information, etc.), to physicians or other experts involved in the treatment, monitoring and evaluation of individuals with MCI and mild, and to road safety policy makers involved in driver licensing and evaluation procedures regarding the vulnerable group of older drivers. The results of this study can potentially contribute to a significant reduction in road accidents and fatalities, which are especially prevalent in Greece.

Apart from the simulator experiment, a future on road driving experiment will strengthen the results and conclude to specific cut-off scores and specific questionnaire based on which the fitness to drive of the older drivers will be assessed.

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