

EFFECT OF ADDITIONAL TASKS IN DRIVING PERFORMANCE: COMPARISON AMONG THREE GROUPS OF DRIVERS

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ABSTRACT: The growing introduction of new technologies inside vehicles represents a set of extra information sources that drivers have to manage at the same time. Their use can interfere with the driving activity and induce performance decrements. An on-road experiment was conducted to investigate how drivers reacted to the inclusion of an additional task and how this situation interfered with guidance and driving activities. Forty eight subjects (elderly, experienced, novice) participated in the tests. During the course they interacted with a navigation system and a mobile phone and were their performance levels evaluated on four parameters: navigation errors, turning indicator activation, visual behaviour and critical situations management. As a result, phone conversation did not significantly affect the guidance task. Concerning the driving, the visual behaviour was less efficient and the activation of the turning indicator was delayed. Young drivers were least affected by the conversation while elderly drivers were the most affected in all the parameters.

1 Background

The development of new technologies and their recent incorporation into road vehicles represents a set of extra sources of information for drivers. This implies drastic modifications of the main activity of driving especially when the driver has to manage simultaneous information from different sources. This information can be linked to the driving activity to assist the driver (such as information from a navigation system or Adaptive Cruise Control) and on the other hand, it can also not be directly related with the driving activity and may enter in the car without any safety device (e.g. mobile phones).

One example of such technology, designed to help the driving task, is the navigation system. Such systems inform the driver about the itinerary, directing him or her to reach a specific place. As soon as the driver enters the destination into the device, the system can select the fastest or shortest route, guiding him/her in the most efficient manner without becoming lost, frustrated or feeling bad about not finding the way. Many studies showed the advantage of using electronic route guidance instead of the old paper map. To Wochinger et al. [1] the interaction with a route system (turn-by-turn) leads to better driving performances than the use of a paper map. The system allows for faster mean speeds on all road types, lower workload ratings and less navigation errors. Moreover, the large amount of cognitive attention required by paper map use leads to a higher rate of abrupt braking manoeuvres [1]. Conversely, a turn by

turn indication presents the relevant information in a simple way. This suggests that a system providing this kind of instructions, rather than complex route information, is less distracting to the driver and presents the most usable means of navigation. Thus the use of a route guidance system is more adequate than paper map use and can efficiently guide the driver in an unfamiliar area [2].

The growing presence of mobile phones inside the vehicle is also a result of the emergence and popularity of communication technologies. Their use is risky and raises the problem of driver distraction. According to Redelmeier and Tibshirani [3], a mobile phone conversation quadruples the risk of being involved in a car crash. Laberge et al. [4] also tried to evaluate this risk by comparing two groups of drivers: users of mobile phone while driving and non users. Their study shows that the risk is 38% higher during a phone call. The main question is to determine in which way a mobile phone conversation diverts the driver's attention and how it interferes with the driving activity. Several studies stressed driving performance impairments in terms of reaction times, decision making, lane keeping [5], and lower driving speed [6]. The quality of perception and information processing is also affected. Indeed, Recarte and Nunes [7] [8] and also Harbluk and Noy [9] showed that the added workload due to a phone conversation increases the driver's effort of attention. At the perception level, this is conveyed by a reduction of the visual attention with a decrease of peripheral stimuli detection like checking the mirror and speedometer [8]. This decrease was explained as the result of a multitasking situation induced by the mobile phone conversation. A secondary task, like a mobile phone conversation, increases the workload, competes with the attention and, as a consequence, diverts the attention away from the primary driving task.

Regarding the use of in-vehicle technology, it can be considered that individual driver's characteristics are very important and can also induce different types of interactions, which may have diverse consequences on behaviour. One of the groups of drivers that studies have been focused on is the "Elderly" due to the fact that they are an increasingly important cluster. Studies have shown that the aging process can induce some decrements in driving ability [10]. Among other examples, some declines are related with the visual, cognitive and motor abilities; difficulty in discriminating relevant information and longer time required to process it; a decline in selective attention and attention switching. The elderly are also characterized by being highly distractible and can also be easily confused by competing sources of information [11]. However in order to compensate their perceptual-motor degradation they tend to adapt their driving behaviour and use residual resources. While driving the elderly try to reduce the stressful mental load they are experiencing and, as a consequence, they are more conscious, drive slowly, and attempt to over control their actions [12]. When interacting with in-vehicle information systems older drivers can express especial difficulties because this interaction may represent a factor of distraction once it imposes the allocation of cognitive resources to an additional task. During this period, they could be temporarily unable to react appropriately to an event or even manage the driving task in complex situations due to the risk of overloading [10].

Liu [13] conducted a study to evaluate the interaction with such systems and tried to check if performances, in terms of reaction time, depended on the modalities of the displays and on the complexity of the messages. Results showed longer reaction times and an increase of the navigation errors for the elderly drivers. They also registered higher performance degradation than novice drivers during complex or critical situations. Dingus et al. [14] also found an age effect and they stated that drivers felt an important workload effect during these situations. The authors explain this tendency by the fact that elderly drivers suffer from an impairment of their cognitive and perceptive abilities and also due to the fact that these systems need a considerable amount of attention to process the information. Due to this gap, elderly drivers felt unable to process the extra information. Indeed, the performance of an in-vehicle task needs interpretation and decision making. All of this could lead to an impairment of the driving activity [15]. Therefore, older drivers require a more stable and user-friendly road environment and in-vehicle information devices should be designed in order to avoid an increase of their mental workload. Unless the systems interfaces and the forecasted interactions are ergonomically designed, they will overload and confuse the driver, especially the elderly [10].

Another group, with extreme importance in the driving context, is the novice due to their higher crash rates [16] [17] [18] [19]. This group is characterized by being more exposed to risk because they drive more often at night [17] [20], travel at higher speeds and at closer following distances [21] [20] [22]. Furthermore, they are more easily distracted by non-driving events [23], they tend to overestimate their driving ability in being over confident of their correction of error [24] [20] [23]. In their literature review, Whelan et al. [25] showed that the lack of skills of novice drivers (information-processing, self-calibration, hazard and risk perception and situation awareness) is related to their crash involvement. Their lower driving experience is frequently associated with less effective approaches to search visual information and with a poorer ability to process the perceived information [26]. Due to this lack of experience, novice drivers have not developed the automatisms in the driving task that allow for fast switching between tasks [23] [27]. They detect hazards slowly and perceive them as less risky [19], therefore being unable to anticipate and control efficiently the vehicle in emergency situations [23]. Furthermore, they may use some devices in a non-optimal way due to their lack of knowledge and risk awareness [23].

The impact of additional tasks on young drivers was also analysed by some authors. Lansdown [28] found driver group differences in the accomplishment of a secondary task where young drivers took longer to react to a stimulus and had higher glance frequency towards the additional task interface. In fact, in multitask situations, novices are not as efficient as experienced drivers for processing useful information due to their lack of ability to automate cognitive processes [29] [28]. Indeed, with increasing levels of experience, the driving activity becomes less demanding and the driver can easily share his/her attention between the driving activity and the secondary task [28]. It seems that experienced drivers are less affected by the secondary task given the fact that they have more ability than novices to share their attention [30]. Moreover, when a situation is cognitively demanding and when it needs a high level of information processing like turning left, Gugerty et al. [31] stressed an impact of

mobile phone use on decision making. This kind of process needs an integration of all the information presented to the driver in order to anticipate the future events and other users' actions.

2 Objectives

Several studies have been conducted in order to investigate the interaction between the driver and one in-vehicle system. However, the increased number of new in-vehicle technologies raises the problem of having several not connected sources of information. Therefore a study was developed in order to investigate how drivers reacted to the inclusion of an additional task and how this situation interfered with driving and influenced the guidance task performance. With more detail, the objective was to analyse the consequence of a mobile phone conversation in the subject's behaviour while driving with a route guidance system. It was important to know how drivers managed both sources of information originated from the guidance system and the mobile phone, which information they prioritised, and also what kind of errors occurred during the driving task.

For this study, it is hypothesised that the mobile phone task will have an influence in both the guidance and driving tasks. In a more specific way, it is expected that the mobile phone conversation poses a negative impact, inducing to a strong decrease in the guidance performance and also to a significant decrement in the driving activity. Concerning drivers' specificities, it is believed that elderly and young drivers will be the groups that perform worse due to the effects of the mobile phone conversation. For the elderly, this result is expected due to their higher difficulty to face the more complex situations, especially considering the simultaneous processing of information from different sources. For young drivers, due to the fact of having less automatic processes, the introduction of an additional task will increase their mental workload and degrade the guidance and the driving task. In spite of the expected inferior results for those two groups of drivers in the presence of the mobile phone, it is hypothesised that these declines will be even more evident for the elderly group.

3 Method

Forty eight drivers took part in the experiment. They were distributed in three groups of 16 participants, depending on their age and driving experience: elderly, reference and young drivers. Elderly participants were aged from 62 to 78 years (mean age=69.4; SD=3.9), reference subjects from 34 to 47 years (mean age=39.6; SD=3.9) and novice drivers from 18 to 21 years (mean age=19.5; SD=1). The elderly and reference subjects had possessed their driving licences for at least five years and have driven in excess of 10000 km. Conversely, novice drivers had less than 2 years of driving experience. An equal number of men and women were represented in each driver group.

All drivers had their own mobile phone: in average, elderly drivers possessed it for almost 5 years ($m=4,63$; $SD=3,49$), reference drivers for 7 years ($SD=2,19$) and novice drivers for 5 years ($SD=1,26$). All but four elderly subjects stated

that they had already used their mobile phone while driving. The majority of elderly drivers admitted to having phone conversations a few times per month while driving. Comparatively, most reference group participants declared having a phone conversation at least several times per week while the majority of young drivers stated to use the mobile phone while driving at least once per day. From the 48 participants only two indicated that they possessed a navigation system, one belonging to the elderly and other to the reference group.

This on-road experiment took place near Lyon (France) with the INRETS vehicle (Institut National de Recherche sur les Transports et leur Sécurité) equipped with sensors that registered the dynamic data of the car. Five mini video-cameras allowed for capturing images from the road environment and the driver and also from the in-vehicle technologies placed in the car. For safety reasons, the car was equipped with another set of pedals in front of the passenger seat and a driving instructor was always seated besides the driver.

A guidance system (Carminat) was fitted as standard to the vehicle and was located on the top of the dashboard to the right of the steering wheel. It displayed schematic guidance instructions throughout arrows (turn-by-turn system) and also transmitted audio instructions some meters prior to intersections.

The recruited participants were asked to drive a predefined course, guided by the instructions of the guidance system and to interact at some specified periods with a mobile phone. Twenty “*target intersections*” were selected from the course in order to be studied with further detail: 8 turns to the right and 12 turns to the left. To be considered as a “*target*”, intersections had to allow the driver to make all the decisions as freely as possible; meaning the driver had to decide when to turn and the decision not influenced by traffic lights or other types of vertical signs.

Subjects only drove the course once and for that reason it was designed to have an equal number of situations in each experiment condition: *No Phone* and *Phone*. In the *No Phone* condition, participants were asked to drive the car with the help of the route guidance system. No other in-vehicle systems were connected nor were other tasks asked of the participants to perform. In the *Phone* condition subjects had to drive the car with the help of the route guidance system and also conduct a mobile phone conversation. Participants interacted with a *bluetooth* hands-free phone connected to the audio system of the vehicle. Two buttons in the centre of the dashboard allowed them to answer the call (left green button) and to hang up (right red button). During the course half of the target intersections were performed without phone (4 right turns and 6 left turns) and the other half with. The system conditions were balanced over the intersections so that half of the subjects in each group performed a set of target intersections in one condition and the other half in the other condition.

The mobile phone task was compiled of a series of sentences sent by a researcher located at INRETS. The participants had to listen to each sentence, repeat it and then answer “Yes” if it was sensible, and “No” if it was not. For example: “Usually, bicycles are bigger than cars” to which subjects had to repeat and then answer “No”. The rhythm with which sentences were given

depended on the pace of the driver to answer the preceding one. This mobile phone task was based on the “Decision part” of the Working Memory Span Test [32] [33]. A repetition part was added to the test in order to ensure that the correct sentence was heard and to better evaluate the accuracy of the answer. All sentences contained 11 or 12 syllables and took an equivalent duration of time to be said. The test contained 50% of sensible phrases and 50% of nonsense sentences. The order in which they were presented was randomly selected by computer utilising a visual basic program made specifically for ordering the sentences.

At the beginning of the experiment, the main objectives of the study were explained to the participants. They were then submitted to visual and audio tests to ensure they had no related problems that could interfere with the experiment and compromise the results. Subsequently, they filled a questionnaire with personal data and also to investigate their opinion and knowledge about new in-vehicle technologies, especially mobile phones and guidance systems. Before the experiment itself, the guidance system functioning as well as the details of the mobile phone task were explained to the participants. A training period of at least 15 minutes allowed them to get familiar with the car, the guidance system and the phone task. The possibility to extend this familiarization period was given to the driver if needed. The experimental test lasted from 30 to 45 minutes depending on traffic conditions, navigation errors and also on the speed of each driver. During the test, an observational table was filled in by a researcher in order to register aspects regarding *navigation, turning indicator signs, driving behaviour, trajectory* of the vehicle, *interaction* with the other road users, respect of *road signs, visual behaviour* towards the more important areas for collecting visual information from the road environment (such as rear mirrors and the intersections itself). Such a table was based on Risser work [34]. At the end of the experiment, participants filled a questionnaire to investigate the attentional demand according to the experimental conditions (*No Phone* and *Phone*).

In spite of several parameters being measured in this experiment (the performance on the primary task, the secondary task and also self-reported measures) only the analysis from the navigation errors and relevant driving errors will be presented in this paper.

4 Results

The variables presented in this paper were only collected at the target intersections because, just in half of those junctions was the mobile phone condition introduced. Due to navigation errors that occurred during the experiment, some participants made small deviations from the original predefined course, resulting in different numbers of target intersections. The allowance for such errors was justified by the fact that drivers should manage their course by themselves in order to find the path and the researcher not allowed to interfere with their decisions. As a consequence, to compare the results, percentages of errors have been computed in each condition. Based on these percentages, results were compared using a statistical test of proportions that was applied in each case (Fisher's test). A significance threshold of 0.05

was accepted ($p < 5\%$). The experimental design included one between-subjects factor: the driver groups (elderly, reference and novice groups) and one within-subjects factor: the driving conditions (Phone and No Phone conditions). Only the statistically significant results are presented.

4.1 Navigation Errors

A navigation error can be considered as a discrepancy between the information sent by the system and the action carried out by the driver. The frequency of such errors was counted and results concluded that from the 843 driven intersections, 42 resulted in navigation errors (approximately 5%). Data showed a higher but non significant percentage of errors in the *Phone* condition (5.91%) compared with the *No Phone* situation (4.12%). Similar results were observed for each driver group, where the *Phone* condition produced a higher percentage of error. Comparing the proportion of errors for the driver groups, elderly drivers made more navigation errors in both *Phone* and *No Phone* conditions. Reference drivers were the ones that made fewer errors and novice drivers positioned themselves in an intermediate position, as shown in Figure 1. It is important to point out that, while in the *No Phone* situation the differences between driver groups are not considerable, for the *Phone* condition the discrepancies are more pronounced, especially between elderly and reference drivers. Although these differences are not statistically significant ($p = 0.07$ between elderly and reference for the *Phone* situation) this shows a tendency for elderly drivers to make more navigation errors while at the phone.

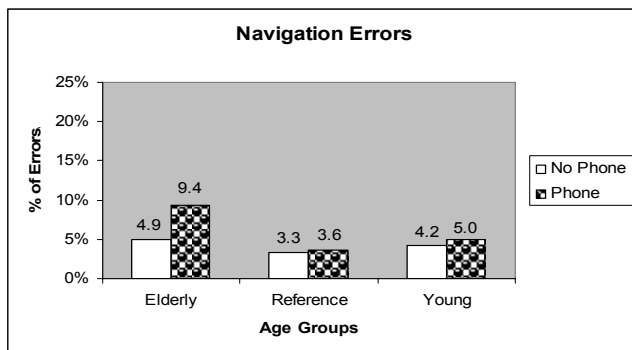


Fig.1. Percentage of navigation errors for each driver group

4.2 Turning Indicators

The number of errors for the turning indicators activation was counted with the help of an observational table and afterwards validated using the video recording of the test. This analysis was divided into two major errors: one characterized by the lack of turning indicator sign (“omission” error), and the other considered when the turning indicator was activated too late, i.e., a par of meters or less from beginning to turn the steering wheel (“timing” error).

By comparing both mobile phone conditions it can be seen that in the *Phone* condition a higher percentage of “omissions” and “timing” errors are observed. It can also be observed that, in this condition, “timing” errors occurred more often

than “omission” errors. In spite of the dissimilarity between both mobile phone conditions not being significant for the “omissions”, for the “timing” errors this difference is statistically significant. Therefore, it can be stated that the *Phone* condition led to a significantly higher percentage of late activations of the turning indicator sign ($p=0.01$). When the comparison between groups is made (Figure 2 and 3), it can be seen that elderly drivers are more likely to forget to activate the turning indicator signal while novice drivers have the smallest “omission” errors percentage. However, the difference is not statistically significant within driver group or between them. The only statistically significant difference occurred for the “timing” errors within the elderly group. Those participants made higher percentage of errors in the *Phone* condition than in the *No Phone* situation (elderly drivers $p= 0.01$), meaning that elderly drivers were the ones significantly more affected by the addition of the phone conversation. This performance decrement was characterized by a latter activation of the turning indicators.

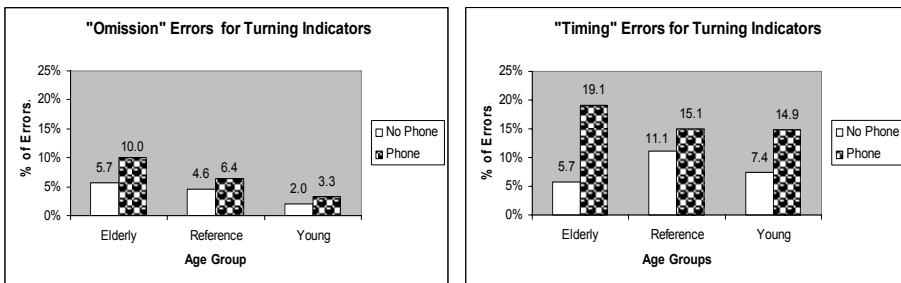


Fig.2. and 3. Percentage of “omission” and “timing” errors for each driver group

4.3 Visual Behaviour

Similar to the turning indicator sign, the number of errors in visual behaviour was coded through the observational table. This register was also made during the experiment and afterwards validated utilising the video recording of the test. The analysis of the visual behaviour was made based on the assumption that drivers have to attend to specific areas of the road environment in order to capture the crucial information to perform a turn. Whenever a driver does not look to these areas, an error was marked down in the table.

From the analysis of the results it is possible to verify that, in a general way, a higher percentage of “visual behaviour errors” were committed in the *Phone* condition. When all subjects are taken into consideration this difference is statistically significant ($p=0.00$). This result is also confirmed for each of the participants’ group where higher percentages of error are observed when a mobile phone conversation is conducted (Figure 4). However, when ages are taken into account, only the elderly and the reference participants reveal a significant difference of errors between mobile phone situations (elderly $p=0.015$; reference $p=0.00$). A comparison between driver groups shows that elderly drivers made more “visual behaviour errors” in both mobile phone conditions. Reference drivers made fewer errors in the *No Phone* situation and their younger counterparts had a lower percentage of error in the *Phone* condition. However, those differences are not significant.

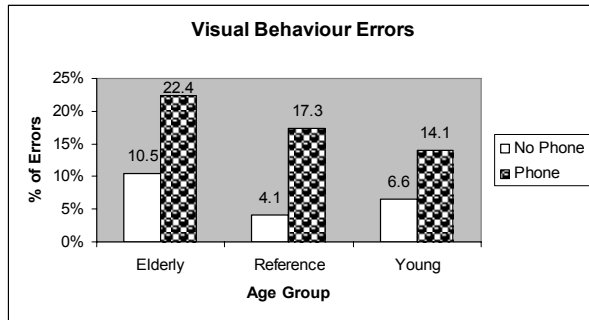


Fig.4. Percentage of “visual behaviour errors” in every age group

4.4 Near Crash Situations

Near crash situations represent the moments where the driver placed himself into a dangerous situation and the instructor, travelling beside him/her, had to intervene. These interventions aimed at avoiding a critical situation or, in the worse case, a crash between the experimental subject and other road users. The instructor could intervene by means of the double pedals installed in front passenger side of the vehicle and also through the direct control of the steering wheel. Such situations occurred during the present experiment. Video recording analysis showed that all the 5 near crash situations registered concerned elderly drivers. Moreover, all but one of these critical events coincided with the usage of the mobile phone. When considering these proportions, the near crash situations in the *No Phone* condition represents less than 1%, while in the *Phone* situation represents 3.13%. This suggests that for the elderly drivers, conducting a mobile phone conversation highly increases their probability of near crash or crash situations.

5 Discussion and conclusion

Regarding the navigation errors, when all driver groups are considered, the analysis of this data revealed a slight tendency of an increasing number of navigation errors in the *Phone* condition. However, contrarily to what was expected, the *Phone* situation did not reveal a statistically significantly higher number of navigation errors. This may be due to the novelty of the guidance task and to the participants' inexperience of interacting with this type of system, leading to numerous navigation errors being made even when drivers were not having a mobile phone conversation. However, this could also be related to the imperfect accuracy of the distance given by the navigation system, which was not always accurate when informing about the number of meters for the next turn (higher speeds also decreased the distance precision). This lack of distance precision could have lead drivers to a higher percentage of errors, even when they were not performing the secondary task. Additionally, it should be considered that the nature and difficulty of the mobile phone conversation did not lead to a sufficient involvement of the experiment participants. This supports the statement saying that, if drivers are not really involved in the conversation, no visible behaviour impairments can be seen [35] [36]. On

revealing that the difference between mobile phone conditions was not significant, it cannot be established that the number of errors is directly attributed to the mobile phone conversation. For this experiment, the mobile phone conversation did not lead to higher percentage of navigation errors. In considering the driver groups, elderly drivers made more errors, especially in the *Phone* condition, where the difference between them and the reference drivers is close to being statistically significant. Thus the elderly show a slight tendency to make more guidance mistakes than reference drivers in a multitask situation.

In considering the turning indicator sign, there was no significant difference for the “omission” errors independently of the mobile phone condition or the driver group. This means that in this experiment, the mobile phone did not produce an important effect by inducing drivers to forget to activate the turning indicators. On the other hand, it can be stated that when all subjects are taken into account, a significantly higher number of late activations of the turning indicator were made coinciding with the phone conversation task. In fact, the detailed analyses of the age groups revealed that elderly drivers were the only group that had higher rates of “timing” errors while using the phone. Neither the reference drivers nor the young drivers drastically changed their “turning indicator” behaviour in the presence of the phone conversation. The data highlights unequal results between age groups and can reveal different ways to process the information. According to Dingus et al. [14] elderly drivers may experience higher difficulties while managing several sources of information and this can lead to a longer information processing. In the present experiment, this higher time to activate the turning indicator sign by the elderly can be considered as the expression of this slowing process.

In the visual behaviour analysis, it is important to highlight that the mobile phone conversation significantly influenced the visual behaviour increasing the percentage of visual errors in this situation. This would suggest that, in the presence of that secondary task, participants more frequently forgot to check some important areas of the environment. The significance of this finding is that dangerous situations could arise as a result of a driver receiving and perceiving less information from the road reducing his/her reactions to an unforeseen event. When age is taken into account, elderly and reference participants committed a significantly higher percentage of errors while using the phone, meaning that the cognitive activity of these two groups of drivers was affected by the presence of the mobile phone conversation. The young driver also made more errors during the phone conversation, but the difference was not significant. According to the literature and supporting the hypothesis in this study, elderly drivers had visual behaviour decrements in the presence of the additional task. Contrarily, the moderate impact of the secondary task on the visual behaviour of the younger drivers' performance did not confirm the results of other studies. This can be justified by the assumption that this group of drivers is more used to interacting with new technologies, coping better with this multitask situation. This is also supported by a higher reported use of mobile phones by this sample as registered in the questionnaire completed prior to the experiment. Using a mobile phone in the car is more familiar to them and the effect is registered as less important on their driving behaviour. This lack of effects from the additional task registered in the young drivers could also be due

to the presence of the driving instructor whose presence could have caused a feeling of being judged. Additionally, the fact of their relative inexperience to driving and probably not having much confidence in their abilities could induce them to pay extra attention to their driving avoiding making mistakes.

The decrements in performance of elderly drivers are once again highlighted when the results of the near crash situations are analysed. The fact that there is a higher percentage of near crashes for elderly drivers in the *Phone* condition reveals that they have more difficulty managing guidance and mobile phone tasks at the same time while driving. This assumption supports literature results that indicate older drivers have more difficulties in processing extra information coinciding with some performance decrement. It should be highlighted that the near crash events during the experiment could have become real crashes without the control of the driving instructor.

The conclusions presented in this paper represent a first look to the results withdrawn from the performed tests. An additional and deeper analysis of the other parameters recorded during this experiment will expand conclusions on this topic and allow for an increased knowledge about the influence of additional and competitive sources of information on the performance of the driving task.

As a conclusion, and contrarily to what was hypothesised, the additional task of the mobile phone did not have a crucial impact on the guidance task and the percentage of navigation errors was not significantly different between mobile phone conditions. However, as expected, the influencing factor was more evident in the driving task because, in an overall review, participants activated the turning indicator later while at the phone. An effect was also found in visual behaviour, where drivers paid less attention to the important areas of the road environment to perform an intersection. As hypothesised, when ages are taken into consideration, it is the elderly whose performance levels change the most in relation to the late activation of the turning indicator and also for flaws in checking the road environment. Like the elderly participants, reference drivers also performed significantly worse in terms of visual behaviour. However, in opposition to the hypothesis, younger subjects did not seem significantly affected by the mobile phone conversation, at least when considering the measures used in this experiment.

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