HOW DOES DISTRACTED DRIVING AFFECT REACTION TIME OF OLDER DRIVERS?

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Abstract

The objective of this research is the analysis of the reaction time of older drivers, while talking on the cell phone and conversing with another passenger. For this purpose, a large driving simulator experiment is carried out, in which 72 drivers from three different age groups (young, middle aged and older) were asked to drive under different types of distraction (no distraction, conversation with passenger, cell phone use) in rural and urban road environment, in low and high traffic. In addition, two unexpected events are set in each driving scenario, where the reaction time of each driver is recorded. To achieve this objective, an appropriate modelling methodology has been developed, including descriptive analysis followed by a generalized linear model and a generalized linear mixed models. Results indicate that both conversing with a passenger and talking on the cell phone, while driving, leads to increased reaction time for all drivers. Female drivers, especially in rural areas, were found to have the worst reaction times, while being distracted (either conversing with a passenger or talking on the cell phone). Furthermore, regarding age groups, older drivers talking on the cell phone achieved the highest reaction time. Results clearly suggest that cell phone use while driving has a potential negative impact on road safety and leads to increased accident risk.

Keywords: Driving Simulator, Road Safety, Reaction time, age group, distraction

Introduction

With the demographic shift towards an ever-increasing number of older drivers on the road, research on older drivers becomes more and more pertinent. In terms of absolute numbers, older drivers are involved in a few accidents; however, they represent one of the highest risk categories for accidents involving fatalities and serious injuries per number of drivers and per distance travelled, probably because of their great fragility and reduced tolerance to injury (Koppel et al., 2008).

As there are a lot of different methods and measures that exist for evaluating driving performance, the selection of the specific measures for driver distraction research, as in other areas of research, should be guided by a number of general rules related to the nature of the task examined as well as the specific research questions (Regan et al., 2008). In this framework, reaction time measures is an increasingly popular set of variables primary because of the relationship with accident risk. A range of reaction time measures can be examined including number of missed events, number of incorrect responses, reaction time and reaction distance (Ishigami and Klein, 2009).

Furthermore, driving simulators have become a widely used tool for examining the impact of driver distraction, with respect to individual driver differences and / or roadway design, as examining distraction causes and impacts in a controlled environment helps provide insights into situations that are difficult to measure in a naturalistic driving environment (Regan et al., 2008).

The objective of this research is the analysis of the reaction time of drivers from different age groups, while talking on the cell phone and conversing with another passenger. The paper is structured as follows: In the beginning, a thorough literature review is presented regarding the effect of cell phone use and age and conversation with the passenger on reaction time through a driving simulator experiments. Then, this large driving simulator experiment is presented, in which participants from three different age groups were asked to drive under different types of distraction (no distraction, conversation with passenger, cell phone use) in rural and urban road environment. Finally, all statistical steps of the analyses are presented (descriptive statistics, Generalized Linear Models (GLM), Generalized Linear Mixed Models, GLMM) and discussed while some concluding remarks are provided.

Background

The term distraction has been defined as "a diversion of attention from driving, because the driver is temporarily focusing on an object, person, task or event not related to driving, which reduces the driver's awareness, decision making ability and/or performance, leading to an increased risk of corrective actions, near-crashes, or crashes" (Young and Regan, 2007).

Driver distraction factors can be subdivided into those that occur outside the vehicle (external) and those that occur inside the vehicle (in-vehicle). The in-vehicle sources of distraction include the use of cell phone (either for conversing or for texting), conversation with passengers, smoking, eating or drinking, listening to music and in-vehicle assistance systems (e.g. navigation systems) (Johnson et al., 2004; Neyens and Boyle 2008), and their effects are largely examined by means of simulator experiments (Horberry et al., 2006; Bellinger et al., 2009). For the purpose of this research, an extensive literature review was carried out, presenting studies on driver distraction examining reaction time measures, with emphasis on the effects of cell phone use and conversation with passengers.

A cell phone conversation distracts drivers by shifting their attention away from the primary driving task. As such, the reaction times of drivers has been of research interest—as a surrogate measure of the crash risk of cell phone distraction—under various study situations including laboratory, driving simulator, and in-field trials.

Burns et al. (2002) investigated the impairment from hands-free and hand-held phone conversations in relation to the decline in driving performance caused by alcohol impairment. Results showed a clear trend for significantly poorer driving performance (speed control and response time) when using a hand-held phone in comparison to the other conditions. The best performance was for normal driving without phone conversations. Hands-free was better than hand-held. Driving performance under the influence of alcohol was significantly worse than normal driving, yet better than driving while using a phone. Drivers also reported that it was easier to drive drunk than to drive while using a phone. It is concluded that driving behaviour is impaired more during a phone conversation than by having a blood alcohol level at the UK legal limit (80mg / 100ml).

Furthermore, a meta-analysis focusing on 33 studies, by Caird et al. (2008), reported a 0.25s increase in reaction times for all types of phone-related tasks and both hands-free and handheld phone conversations had similar effects on reaction times. Another meta-analysis of 23 studies revealed that cell phone distraction increased the response times to unexpected hazards with similar effects for both hands-free and handheld phone conditions (Horrey and Wickens, 2006). In this framework, a review by Ishigami and Klein (2009) reported a similar conclusion where drivers distracted by either hands-free or handheld phone conversations revealed slower reaction times.

Several studies have examined the influence of driver demo-graphics like age and gender on reaction times of distracted conditions. Similar impairment of reaction times was reported by Caird et al. (2008), where there action times were 0.46 s and 0.19 s slower, respectively, for distracted older and young drivers. An experiment on an advanced driving simulator by Nilsson and Alm (1991) showed that elderly drivers' reaction times to an unexpected event were approximately 0.40 s greater than that for young drivers when distracted by a cell phone conversation

Hancock et. al., 2003, tested forty-two licensed drivers in an experiment that required them to respond to an in-vehicle phone at the same time that they were faced with making a crucial stopping decision. Results confirmed that in the dual-task condition there was a slower response to the light change. To compensate for this slowed response, drivers subsequently braked more intensely. Most importantly, a critical 15% increase in non-response to the stop-light in the presence of the phone distraction task was recorded which equates with increased stop-light violations on the open road. Furthermore, regarding the effect of gender, cell phone distraction had a greater influence on females than males with corresponding impairments on reaction times 0.25 and 0.14 respectively. Finally, the reaction times of older drivers appear to be impaired by 0.29 s by a cell phone conversation, while the corresponding impairment of young drivers is only 0.11 s —less than half of older drivers

Methodology

Data Collection

Driver distraction 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.

Overview of the Experiment

Within this research, a large driving simulator experiment was including different driving scenarios. The design of the distracted driving scenarios is a central component of the experiment and includes driving in different road and traffic conditions, such as in a rural, urban area with high and low traffic volume. More specifically, this assessment includes an urban driving session with up to six trials and a rural driving session with up to six trials. These trials aim to assess driving performance under typical conditions, with or without external distraction sources. The driving simulator experiment takes place at the Department of Transportation Planning and Engineering of the National Technical University of Athens, where the Foerst Driving Simulator FPF is located. It is a quarter-cab simulator with a motion.

Familiarisation

A familiarization session or 'practice drive' is typically the first step of all simulator experiments. During the familiarization with the simulator, the participant practiced in handling the simulator (starting, gears, wheel handling etc.), keeping the lateral position of the vehicle, keeping stable speed, appropriate for the road environment and braking and immobilization of the vehicle. When all criteria mentioned above were satisfied (there was no exact time restriction), the participant moved on to the next phase of the experiment

Driving at the Simulator

After the practice drive, each participant drives the two sessions (approximately 20 minutes each). Each session corresponds to a different road environment:

- A rural route that is 2.1 km long, single carriageway and the lane width is 3m, with zero gradient and mild horizontal curves.
- 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.

Within each road / area type, two traffic scenarios and three distraction conditions are examined in a full factorial within-subject design. The distraction conditions examined concern undistracted driving, driving while conversing with a passenger and driving while conversing on a cell phone.

The traffic scenarios are:

- QL: Moderate traffic conditions - with ambient vehicles' arrivals drawn from a Gamma distribution with mean m=12 sec, and variance σ2=6 sec2, corresponding to an average traffic volume Q=300 vehicles/hour.
- QH: High traffic conditions - with ambient vehicles' arrivals drawn from a Gamma distribution with mean m=6 sec, and variance σ2=3 sec2, corresponding to an average traffic volume of Q=600 vehicles/hour.

Consequently, in total, each session (urban or rural) includes six trials, i.e. six drives of the simulated route.

Incidents

During each trial of the experiment, two unexpected incidents occur at fixed points along the drive (but not at the exact same point in all trials, in order to minimize learning effects). More specifically, incidents in rural area concern the sudden appearance of an animal (deer or donkey) on the roadway, and incidents in urban areas concern the sudden appearance of an adult pedestrian or of a child chasing a ball on the roadway.

Randomisation

The first principle of an experimental design is randomization, which is a random process of assigning treatments to the experimental units. The random process implies that every possible allotment of treatments has the same probability. An experimental unit is the smallest division of the experimental material and a treatment means an experimental condition whose effect is to be measured and compared. The purpose of randomization is to remove bias and other sources of extraneous variation, which are not controllable. Another advantage of randomization (accompanied by replication) is that it forms the basis of any valid statistical test (Boyle, 2011).

Sample

The sample of participants is 87 healthy participants aged 18-75 years old. More specifically, 32 young drivers aged 18-34 years old, 33 middle aged drivers aged 35-54 years old and 22 older driver aged 55-80 years old consist the sample of the analyses.

Analysis methods

To achieve the objectives set out in this paper, an appropriate modeling methodology - presented in this section - has been developed, regarding reaction time. The methodology is consisted of several steps as follows.

In the first step, in order to analyze these key measures, a descriptive analysis took place through box plots. A box plot (also known as a box-and-whisker chart) is a convenient way to show groups of numerical data, such as minimum and maximum values, upper and lower quartiles, median values, outlying and extreme values.

The spacing between the different parts of the box plot indicates the degree of dispersion (spread) and skewness in the data and identifies outliers. More specifically, regarding box plots:

- The line in the middle of the boxes is the median
- The bottom of the box indicates the 25th percentile. Twenty-five percent of cases have values below the 25th percentile.
- The top of the box represents the 75th percentile. Twenty-five percent of cases have values above the 75th percentile.
- Half of the cases lie within the box.

In the next step, in order to estimate the effect of cell phone while driving in different age groups, generalized linear models were developed as they facilitate the analysis of the effects of explanatory variables in a way that closely resembles the analysis of covariates in a standard linear model, but with less confining assumptions. This is achieved by specifying a link function, which links the systematic component of the linear model with a wider class of outcome variables and residual forms.

A key point in the development of GLM was the generalization of the normal distribution (on which the linear regression model relies) to the exponential family of distributions. Consider a single random variable y whose probability (mass) function (if it is discrete) or probability density function (if it is continuous) depends on a single parameter θ. The distribution belongs to the exponential family if it can be written in the form (Eq. (1)):

$$f(y;\theta)=s(y)t(\theta)e^{a(y)b(\theta)} \quad (1)$$

where a, b, s, and t are known functions. The symmetry between y and θ becomes more evident if Eq. (1) is rewritten as Eq. (2):

$$f(y;\theta)=\exp\left[a(y)b(\theta)+c(\theta)+d(y)\right] \quad (2)$$

where s(y)=exp[d(y)] and t(θ)=exp[c(θ)]. If a(y)=y then the distribution is said to be in the canonical form. Furthermore, any additional parameters (besides the parameter of interest θ) are regarded as nuisance parameters forming parts of the functions a, b, c, and d, and they are treated as though they were known. Many well-known distributions belong to the exponential family, including –for example– the Poisson, normal, and binomial distributions. On the other hand, examples of well-known and widely used distributions that cannot be expressed in this form are the student’s t-distribution and the uniform distribution.

In the third step, generalized linear mixed models are implemented as the data used in this research involve repeated measures observations from each individual drive (each driver completes six drives in rural and six drives in urban environment). When dealing with such panel data it is often useful to consider the heterogeneity across individuals, often referred to as unobserved heterogeneity. The generalized Linear mixed Model generalizes the standard linear model in three ways: accommodation of non-normally distributed responses, specification of a possibly non-linear link between the mean of the response and the predictors, and allowance for some forms of correlation in the data. (Breslow and Clayton, 1993).

Finally, in order to confirm that the random effect was statistically significant, and therefore the Generalized Linear Mixed Models were superior to the respective Generalized Linear Models, likelihood ratio test (Ben Akiva and Lerman, 1985) were performed between each set of models. The likelihood ratio test (LRT) is a statistical test of the goodness-of-fit between two models. A relatively more complex model is compared to a simpler model to see if it fits a particular dataset significantly better. If so, the additional parameters of the more complex model are often used in subsequent analyses. The LRT is only valid if used to compare hierarchically nested models. That is, the more complex model must differ from the simple model only by the addition of one or more parameters. Adding additional parameters will always result in a higher likelihood score. However, there comes a point when adding additional parameters is no longer justified in terms of significant improvement in fit of a model to a particular dataset. The LRT provides one objective criterion for selecting among possible models.

The LRT begins with a comparison of the likelihood scores of the two models:

$$LR = 2*(\ln L_R - \ln L_U) \tag{3}$$

where L_R is the likelihood for the null/restricted model, while L_U is the likelihood for the alternative/unrestricted model.

This LRT statistic approximately follows a chi-square distribution. To determine if the difference in likelihood scores among the two models is statistically significant, we next must consider the degrees of freedom. In the LRT, the degrees of freedom are equal to the number of additional parameters in the more complex (unrestricted) model. Using this information we can then determine the critical value of the test statistic from standard statistical tables.

All statistical analyses have been implemented and estimated in the R language for statistical computing (R Development Core Team, 2014).

Results

In this section, all stages of the statistical analyses are presented together with an interpretation of the modeling results. Beginning with the descriptive analyses, in Figure 1, the reaction time of drivers is presented per distraction factor (no distraction, conversation with the passenger, cell phone use) and per age group (young, middle aged, older).

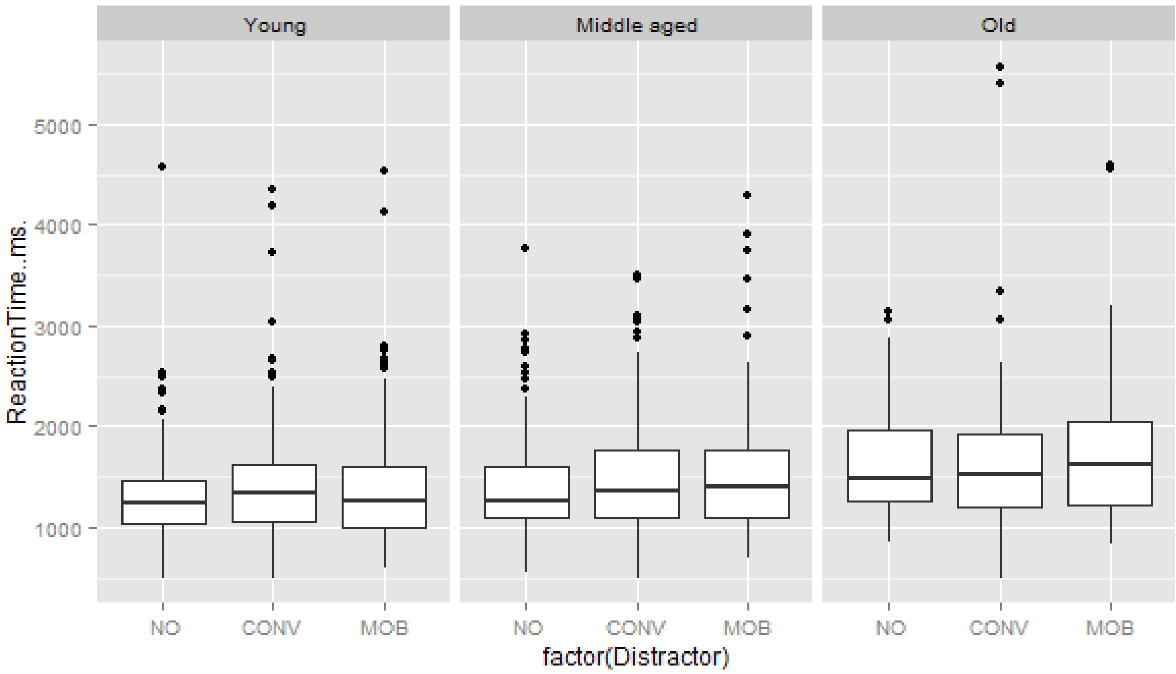

Figure 1 - Reaction time per distraction factor and age group

It is clearly observed that while talking on the cell phone or conversing with passenger, drivers of all age groups have higher reaction times compared with undistracted driving. Furthermore, it is very interesting that young and middle aged drivers indicate higher reaction times when conversing with the passenger that talking on the cell phone. On the other hand, older drivers have the worst reaction time when talking on the cell phone.

In the next step, generalized linear models were developed regarding the reaction time of the drivers. The parameter estimates and their statistical significances are summarized in the left part of Table 1. It is noted that a variable is considered to be statistically significant at a 90% confidence interval, when its t-value is higher than 1.64 and consequently its p-value is lower than 0,100.

Before accepting the results of both generalized linear models it is important to evaluate their suitability at explaining the data. One of the many ways to do this is to visually examine the residuals. If the model is appropriate the residual errors should be random and normally distributed. In addition, removing one case should not significantly impact the model's suitability. R provides four graphical approaches for evaluating the model of reaction time as presented in Figure 2.

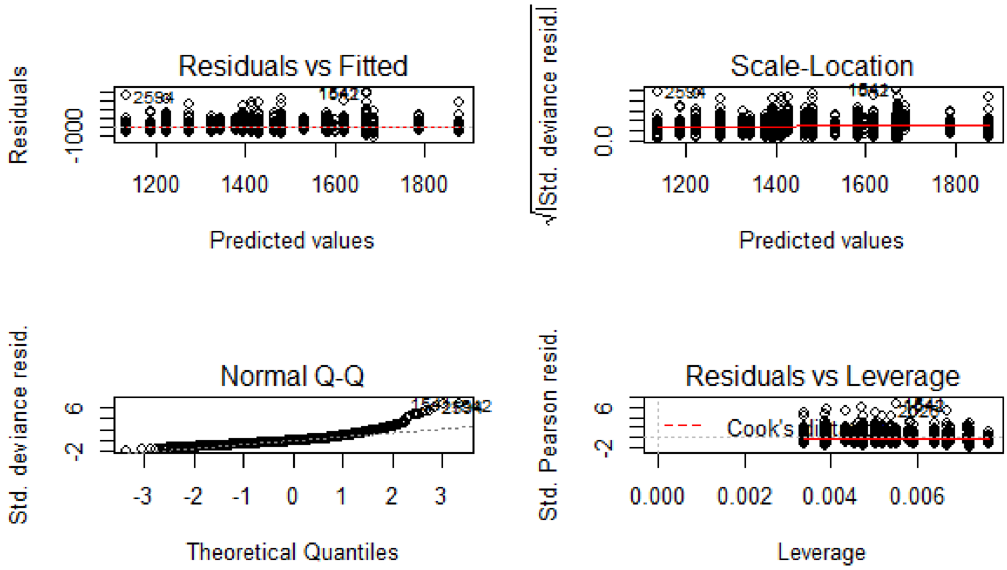

Figure 2 - Reaction time GLM graphical approach of residuals

The plots in the upper left of each Figure show the residual errors plotted versus their fitted values. The residuals should be randomly distributed around the horizontal line representing a residual error of zero (there should not be a distinct trend in the distribution of points). The scale location plots in the upper right show the square root of the standardized residuals as a function of the fitted values. Again, there should be no obvious trend in this plot. The plots in the lower left are standard Q-Q plots, which should suggest that the residual errors are normally distributed, if the residuals fall on the dotted line. Finally, the plot in the lower right shows each point's leverage, which is a measure of its importance in determining the regression results. In Figure 2 all graphical approaches confirm the suitability of the model of reaction time.

However, as described in the methodology chapter, the data used in this research involve repeated measures observations from each individual drive, as each driver completes six drives in rural and six drives in urban environment. For this reason, in order to deal with the heterogeneity across individuals, generalized linear mixed models are implemented and presented in the right part of table 1.

Results of both models indicate that specific parameters affect reaction time of drivers. More specifically, age has the higher effect on reaction time as older drivers have the worst reaction times comparing to young and middle aged. Area type is also critical as in urban areas, especially male drivers, seem to be more concentrated on driving probably due to the complex environment and have lower reaction times than in rural areas.

Furthermore, focusing on the effect of distractions factors, it can be assumed that the increase in reaction time of all drivers while talking on the cell phone or conversing with the passenger has a totally negative impact on road safety. In particular, looking at the parameter estimates of this model, cell phone use has higher impact on reaction time than conversing with the passenger in the whole sample.

Table I - Parameter estimates of the GLM and GLMM of Reaction time

	Generalised Linear Model		Generalised Linear Mixed Model	
Variables	**Est.**	**t value**	**Est.**	**t value**
Intercept	1.562,98	44,00	1.566,05	37,60
Age group = Old	234,29	5,85	236,38	4,54
Distraction - Conversation	73,57	1,95	71,47	1,93
Distraction – Cell phone	100,87	2,45	112,05	2,74
Gender - Male	-190,30	-5,74	-192,78	-5,89
Area type - Urban	-216,52	-6,66	-218,52	-5,00
Summary statistics				
df	7		8	
Initial Log-Likelihood	-9.460,96		-9.428,39	
AIC	18.935,00		18.872,00	

Finally, the likelihood ratio test is taking place in each examined pair of model in order to examine the goodness-of-fit. Regarding reaction time models LRav.speed= -64,53 (1 degree of freedom) indicating that the random effect contributes significantly to the fit of the model and therefore the fit of the generalized linear mixed models outperforms respective generalized linear models.

Conclusions

This paper analyzed the driving performance of drivers of different age groups in order to investigate the effect of age and distraction on reaction time. For this purpose, 72 participants from three different age groups were asked to drive under different types of distraction (no distraction, conversation with passenger, cell phone use) in urban and rural road environment with low and high traffic volume. Results suggest that the specific methodology and design confirm the initial hypotheses and may reveal differences between driving without any distraction source and talking on the cell phone on the reaction time of different age groups.

Results indicate that reaction time of the drivers at unexpected incidents exhibited differences between talking on the mobile phone, conversing with the passenger and driving without any distraction. It is clearly observed that, while talking on the mobile phone or conversing with passenger, drivers of all age groups have higher reaction times compared with undistracted driving. Furthermore, it is worth noting that young and middle aged drivers indicate higher reaction times when conversing with the passenger than talking on the mobile phone.

This is explained by the different distraction mechanism between cell phone and conversation with the passenger which is correlated with driver’s age. Mobile phone use distraction is consisted of prolonged and repeated glances to the mobile and older drivers have difficulty in maintaining mobile devices while driving because they are not as practiced and efficient as technological multi-taskers when compared to younger drivers. On the other hand, when conversing with the passenger, drivers' glance is out of the road very often and this has a more often effect on reaction time of young and middle aged drivers.

Furthermore, female drivers, especially in rural areas, were found to have the worst reaction times, while being distracted (either conversing with a passenger or talking on the cell phone). This is probably explained by the fact that in urban area, the complex road environment alerts the drivers in order to self-regulate their driving to compensate for any decrease in attention to the driving task.

The next steps of the present research could focus on the investigation of impact of cell phone use, not only when the drivers talk on cell phone using a hand-held device but also when they use a hands-free device, a Bluetooth, or when they type messages.

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